ASSESSING THE ECOLOGICAL CONDITION OF WETLANDS IN THE LOWER MISSOURI RIVER FLOODPLAIN

BY

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Abstract

Changes to the hydrology of the Missouri River and its associated floodplain have dramatically reduced historic flooding cycles, thereby reducing wetland area as well as the ecological integrity of remaining wetlands. This study assesses the ecological condition of wetlands within the Lower Missouri River estimated 500-year floodplain (from Sioux City to St. Louis). The sample population comprises 17 wetlands sampled as part of a “reference” study done in 2005 and an additional 42 wetlands sampled randomly in 2008 and 2009. Wetlands were classified, assessed for disturbance and sampled for a suite of floristic and water quality variables. High conductivity was associated with degraded floristic quality in all wetlands (within regional groups), whereas total nutrient ratios (TN:TP) appeared to have class-specific impacts. Total phosphorous, pH, floristic richness and mean conservatism also grouped by region. However, most water quality variables were found to vary significantly within individual wetlands and by wetland classes. Findings suggest that alterations to structural factors or morphological attributes within wetlands may have more significant impacts on wetland condition than surrounding disturbance or regional trends in disturbance.

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I. Introduction

> *The common belief became that many extremes (rainfalls, floods, droughts) can be anticipated, and their consequences can be prevented or diminished, with a technical approach. Those measures proved their effectiveness under normal conditions, with a high naturalness of landscape and steady landscape and ecosystem processes. However, under increasing climate variability, demographic growth, land use changes and remnants of past improper resource management and exploitation, these measures became questionable. They appeared to be unable to deal with increasing uncertainty of appearance, scale, reversibility, and damage potential of water-related risk.*
>
> *Krauze and Wagner 2008*

In the early 20th century, channelization of the Lower Missouri River for navigation purposes was accompanied by the construction of flood control/irrigation structures within its floodplain. These technical measures were intended to meet the needs of commerce and agricultural development. Today, however, the cumulative ecological and economic consequences of these alterations have yet to be fully understood. Overall, there is less hydrological interaction between the river, its historical floodplain and associated wetlands with respect to participation in annual flooding cycles (Galat *et al.* 1998). In addition, there is recent evidence of more extreme flooding events (*e.g.* The Great Midwest Flood of '93) that may be exacerbated by the separation between the river and its historical floodplain. Research at the turn of the 21st century has demonstrated the long-term importance of lateral connections within floodplains and their pivotal role in maintaining biodiversity and ecological functioning at local and regional scales (Verhoeven *et al.* 2008; Mitsch and Gosselink 2000; Mitsch *et al.* 1998; Galat *et al*. 1998).

Wetlands are crucial to the relationship between the Missouri River and its floodplain. Current wetland conditions can indicate the status and trends of residual river-floodplain interactions and their potential for enhancement. Meanwhile, developing a method to assess the condition of remnant wetlands within the Lower Missouri River floodplain may give insight into how specific hydrologic alterations impact wetland condition by characterizing the extent of wetland impairment according to varying degrees and types of human disturbance.

1.1 Summary of study area and project foundations

The lower one-third of the Missouri River extends 1178 km downstream from Sioux City, Iowa to St. Louis, Missouri and drains one-sixth of the continental United States. Braided shifting channels, innumerable snags, and countless migrating sand islands and bars characterized the "precontrol" Missouri River (Galat *et al.* 1998). Today, approximately 10% of the original lower reach of the Missouri River floodplain is inundated during the average annual flood pulse compared with before the river was impounded and channelized (Hesse *et al.* 1989). Over three million acres of natural river habitat have been altered, 51 of 67 native fish species are now rare and aquatic insects have been reduced by 70% according to the Missouri River Recovery Program (www.moriverrecovery.org).

This study uses a reference-based approach to characterize the conditions of wetlands located within the 500-year floodplain of the Lower Missouri River. Both the application of a reference-based approach and the collection of ecological information on the condition of Lower Missouri River floodplain wetlands are consistent with the priorities of the United States Environmental Protection Agency (EPA) Region 7 Office (Nebraska, Iowa, Kansas, and Missouri). The work published in this thesis is part of a larger project, which was funded by EPA Region 7 in two parts (Phase I and II of The Assessment of Floodplain Wetlands of the Lower Missouri River) and carried out by researchers at the Central Plains Center for BioAssessment (CPCB).

Phase I of the Assessment of Floodplain Wetlands of the Lower Missouri River was completed in 2007 with the intention of characterizing “reference” conditions for floodplain wetlands that were 10-acres or larger and excluded woody palustrine. Phase II (2008-2009) was meant to estimate the status ecological conditions of the floodplain wetland population using the US EPA’s Environmental Monitoring and Assessment Program (EMAP) study approach and randomized site-selection. The tasks of developing and refining assessment tools in addition to formulating a strategy for evaluating overall wetland condition span both project phases (2005-2009).

For this thesis, wetlands from Phases I and II were combined and then regrouped along a disturbance gradient that was determined by the disturbance assessment developed in Phase II. The development and application of these tools present a reference-based strategy to assess the ecological condition of wetlands throughout the Lower Missouri River floodplain.

1.2 Thesis objectives

- *Establish a conceptual basis for describing a range of wetland conditions*
- *Evaluate the efficacy of wetland detection parameters and site selection*
- *Develop, justify and refine a viable floodplain wetland disturbance assessment*
- *Determine extent of structural, local and regional influences on wetland condition*

1.3 The concept of reference condition

The notion of a reference-based study is modeled after contemporary methods used in the classification of stream reference conditions (Stoddard *et al.* 2006). Stream reference conditions (for biological integrity) can be classified as historical conditions (HC), best attainable conditions (BAC), least disturbed conditions (LDC) and minimally disturbed conditions (MDC). The type of reference condition that can be most effectively applied depends on the nature and context of what is being studied, in this case transitional ecosystems within a highly altered floodplain.

Historical conditions are those that existed before human settlement and subsequent disturbance. For the Lower Missouri River floodplain, a definition of historical condition is not possible because quantitative pre-settlement data are not available. Minimally disturbed conditions refer to preserved aquatic ecosystems that have been purposely or accidentally isolated from most human disturbance. Put simply, the occurrence of minimally disturbed conditions within the study area is probably too low for reference characterization. Best attainable conditions represent the best possible condition in light of the permanent disturbances that have occurred in the landscape. However, the assumption of permanent disturbance is unable to account for management practices that may fluctuate from year-to-year and landscape transformations caused by low-recurrence flood events. Variations in ecosystem response for least disturbed conditions are a result of natural differences as well as changes in the intensity and impact of disturbance over time.

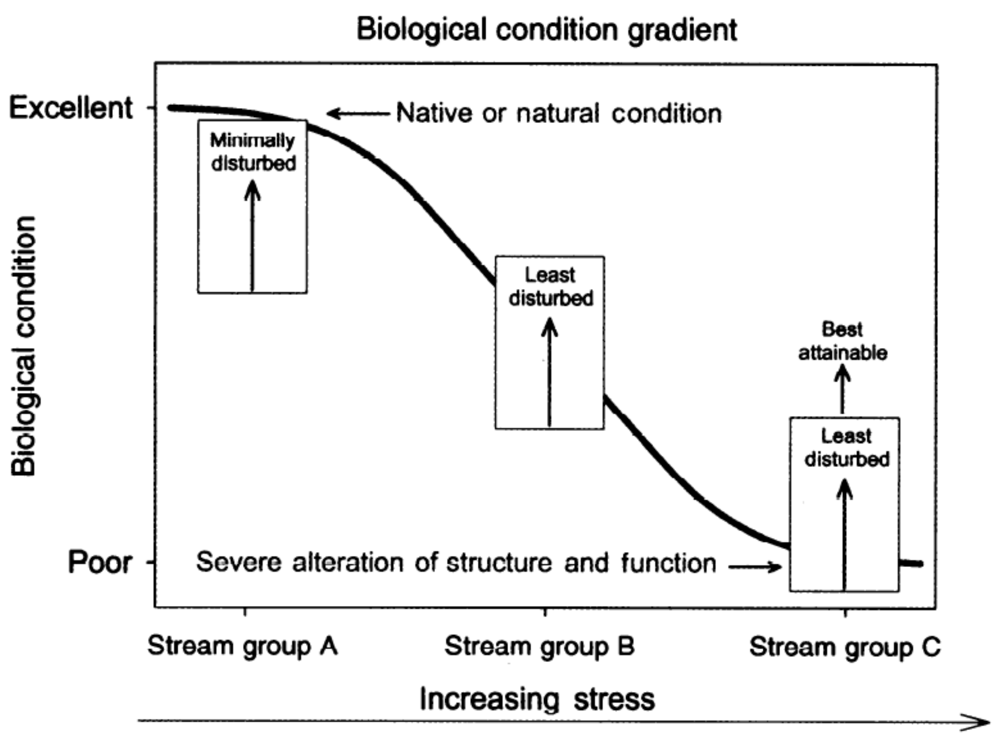

Figure 1: Minimally disturbed and least disturbed reference conditions shown as a conceptual relationship between human disturbance (stressors) and biological condition. From Stoddard *et al*. 2006.

LDC's and MDC's occur along a biological integrity gradient that shows a negative relationship when plotted against human disturbance (Figure 1). The assumption is that MDC's would be present in native or undisturbed wetlands, whereas LDC's may constitute the closest semblance to native wetlands in a highly disturbed watershed. Therefore, least disturbed conditions are the conceptual basis for describing reference conditions among wetlands within the Lower Missouri River floodplain.

1.4 Preliminary considerations for reference characterization

For each phase of this research, lacustrine and palustrine wetland systems (10-acres and larger and not woody or riparian) were initially selected using the US Fish and Wildlife Service's National Wetlands Inventory (NWI), which is based upon the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin *et al*. 1979). Both palustrine and lacustrine systems are composed of littoral zones inhabited by similar vegetation communities.

Lacustrine systems characteristically have extensive areas of deep water (greater than 2-m) and considerable wave action. They can be composed of both limnetic and littoral zones, with persistent emergents and other vegetation covering less than 30% of the total wetland area. Cowardin *et al.* (1979) chose the 2-m lower limit for inland lacustrine wetlands because it represents the maximum depth at which emergent plants are typically able to grow and thus facilitates the occurrence of a limnetic subsystem or "deepwater habitat".

The littoral zone can be composed of trees, shrubs, persistent emergents, emergent mosses or lichens and lies between the shoreline and limnetic zone, which begins at the 2-m depth. The littoral zone could also be referred to as a palustrine system. According to Cowardin *et al.* (1979), palustrine systems were developed to group wetland habitats traditionally called by such names as marsh, swamp, bog, fen and prairie. Palustrine systems can be situated shoreward of lakes and river-channels or as islands within either, in floodplains, on slopes and in isolated catchments. For these systems wind and erosion are of minor importance except during severe flooding events.

True lacustrine systems were seldom found in this study because of insufficient wetland vegetation and misclassification by NWI. Many wetlands identified in the NWI as “lacustrine” sites did not meet the 2-m depth criterion (explained further in Section II). Sites composed almost entirely of limnetic zones over 2-m deep were inadequate for a Floristic Quality Assessment (FQA) of wetland-specific vegetation because of steep banks and rocky, woody, or manicured shores (*i.e.* they were not vegetated).

After establishing least disturbed conditions as the baseline for reference wetlands, researchers needed a way to measure varying degrees of human disturbance. Initially, reference characterization was done using GIS techniques and field visits. Ultimately the GIS techniques proved to be a means for producing a group of potential reference sites. These sites had to be confirmed or rejected based upon professional judgment and ground-truthing during field evaluation visits. At this point, wetlands could be classified as reference or non-reference based on surrounding land-use, but the *range* of disturbance indices required for a large-scale condition assessment had not been sufficiently developed or quantified. A more robust description of least disturbed reference conditions was needed so that the general condition of wetlands might be related to varying degrees of human disturbance. A Rapid Assessment Method approach to quantifying disturbance, later referred to as the Floodplain Wetland Disturbance Assessment, was used to verify reference conditions and describe a range of disturbance relative to the population of wetlands sampled during the Phase II study, which is discussed in Section IV.

II. Site-selection

2.1 Determination of study population

Phase I sites were selected based on their potential as least disturbed reference candidates using GIS techniques and best professional judgment. The US Fish and Wildlife Service's National Wetlands Inventory (NWI) was the primary data source used to identify potential wetland polygons within the 500-year Missouri River floodplain. NWI maps were prepared by analyzing high-altitude imagery for vegetation, visible hydrology, and geography. Because of certain limitations in using this imagery, NWI wetland detection, delineation and classification can sometimes be inaccurate. Originally, CPCB proposed sampling 20 palustrine and 20 lacustrine sites as classified by NWI during Phase II of the floodplain study. Sites from the NWI database defined as less than 10 acres in size were not considered in either of the initial study populations because there was a high probability that they would be misclassified by NWI. Conversely, the 10-acre size criterion would also ensure a higher likelihood of open water during the sampling season based on the fact that larger wetlands tend to exhibit more recognizable wetland functions and biodiversity.

Generalized Random Tessellation Stratified (GRTS) Survey Designs were used to encourage spatial balance and randomized site-selection for the Phase II condition assessment. GRTS designs use a hierarchical grid placed over a given geographical area, in this case the Lower Missouri River 500-year floodplain. Grid quadrants or polygons are then labeled randomly and organized into a sample line. To create the sample/oversample list, a random starting point is selected and the sample line is followed in reverse hierarchical order. This process attempts to alleviate artificial clustering that occurs as a result of applying "uniform" sampling techniques to non-uniform distributions of natural features (*e.g.* wetland complexes or aquatic ecosystems in general).

In February of 2008, researchers at CPCB received a list of randomly selected sites from Dr. Tony Olsen (USEPA NHEERL Corvallis) and began building a Phase II floodplain wetland database containing land ownership information and individual site characteristics. Abbreviated sample population databases containing coordinates and target-site names are shown in Appendix A and B. To promote more geographic uniformity in the selection process, the Lower Missouri River floodplain was divided into three strata (upper, middle and lower) and by system (lacustrine and palustrine). These selections were then evaluated in the numerical order according to the original database provided by EPA.

2.2 National Wetlands Inventory (NWI) veracity for target sample population

NWI polygons selected for possible study were ground-truthed by CPCB researchers during reconnaissance visits conducted in late spring before each subsequent sampling season. Sites listed as lacustrine or non-woody palustrine that failed to meet either the hydrological or biological definition of these two wetland types were listed as NT (non-target) and rejected from the study. If researchers were denied permission to visit sites on private property, the site was labeled LD for landowner denial and also rejected. Site folders for NT and LD sites have been maintained and filed separately from the target sample population (n=42). Site folders containing evaluation forms and maps of individual wetlands were created to complement the database. The preliminary evaluation form for lacustrine and palustrine wetlands is based on classification schemes found in Cowardin *et al*. 1979. This form consisted of landowner contact information, access notes, wetland system descriptions (lacustrine and non-woody palustrine) and a rudimentary disturbance assessment (*i.e.* least, moderately, or highly disturbed).

There are often great similarities between wetlands lying adjacent to lakes or rivers and isolated wetlands of the same class in basins without open water (Cowardin *et al.* 1979). After ground-truthing, all lacustrine sites retained as part of the sample group were ultimately reclassified at the class-level, instead of being grouped at the system-level. Technically, all palustrine systems should be less than 20 acres in size (Cowardin *et al.* 1979). If a wetland is over 20 acres in size, it is assumed to be lacustrine, whether it reaches 2-m in depth or not. However, if the wetland is less than 20 acres in size and does reach 2-m in depth at some point, it is said to be lacustrine. These distinctions became arbitrary for this study because few wetland systems were found to be over 2-m in depth within the Missouri River floodplain and wetland size was more often found to be restricted by artificial circumstances (*i.e.* impoundment, drainage) rather than natural ones.

Of the lacustrine systems identified by NWI and evaluated during the Phase II study (n = 58; excluding landowner denials), only 20% met all three of Cowardin's lacustrine system's criteria and were thus correctly classified by NWI. About 38% of all NWI lacustrine sites evaluated did not have limnetic zones, meaning they were not sufficiently distinguishable from palustrine sites. The remaining 42% of NWI lacustrine sites were composed entirely of deepwater habitat, row-crops, pasture or woods, in which case they were not wetlands. No major variations between NWI detection for lacustrine systems were observed between the upper, middle and lower regions.

For palustrine systems identified by NWI (n = 98; excluding landowner denials), only 20% were classified correctly as wetlands. The rest of the sites were found to be row-crops, woods or pasture areas and thus were not considered wetlands. Researchers concluded that NWI misclassifications could result from regional characteristics and the difficulty of accurately estimating water-depth from high-altitude imagery. While NWI misclassification of lacustrine systems seemed to be regionally unaffected, the classification accuracy of palustrine systems did vary. For the upper reach, 47% of palustrine systems were correctly identified. This number was smaller (28%) for the middle reach and was just 10% for the lower reach. Most of the sites visited and deemed non-target in the lower reach were cropped or wooded.

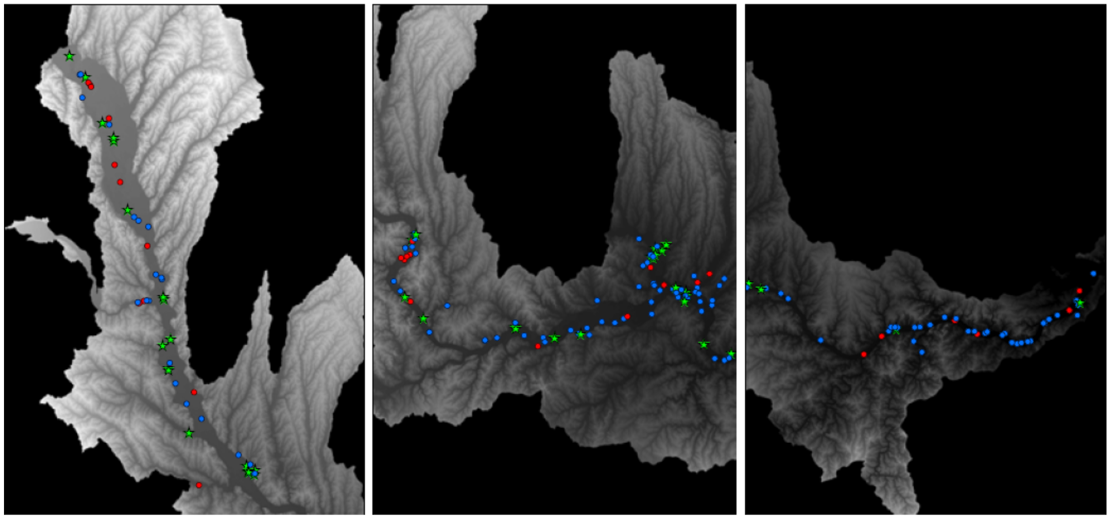

Figure 2: Site distribution for Phase II using NWI within the 500-year floodplain of the Missouri River. Left to right shows DEM maps of Upper, Middle and Lower reaches. Green = sampled site (TS), blue = non-target (NT) and red = landowner denial (LD).

It was evident to the researchers that sites misclassified by NWI could have been wetlands at some point in their history, which is a testament to the inventory's ability to identify historical wetland sites based on trends in topography and the persistence of artificially drained hydric soils. It also suggests that there have been more alterations to hydrology and efforts toward burn suppression in the lower reach of the study area relative to the middle and upper reaches.

III. Floodplain Wetland Classification

3.1 Hydrogeomorphic vs. Cowardin et al. (1979)

At present, there are two major approaches to wetland classification: the Hydrogeomorphic (HGM) Classification scheme and that of Cowardin *et al.* 1979 mentioned in the previous sections. The coexistence of these classification schemes reflects a fragmented approach to intrinsic wetland valuation because each classification scheme is used to group wetlands according to specific functions being assessed (including "condition" as a *function* of ecological integrity), instead of considering multiple functions simultaneously. These classification schemes set the foundations for conflicting interpretations of wetland hydrologic function and ecological condition.

This study's emphasis on hydrology within a large floodplain suggests the use of a modified HGM Classification scheme. However, the classification scheme of Cowardin *et al.* (1979) is better suited for developing a detailed description of wetland plant communities. Hydrogeomorphic (HGM) Classification considers geomorphic setting, water sources and hydrodynamics in describing the functional attributes of wetland classes according to their hydrologic characteristics (Brinson 1993). Yet, HGM classes do not fully account for differences in how wetlands behave as wildlife habitat and under specific management scenarios; nor do they distinguish between natural and artificial morphological attributes.

3.2 Justification for using Cowardin et al. (1979)

In attempting to classify wetlands within a highly disturbed floodplain, it was necessary to consider management activities. Just as present vegetation communities depend on phases of temporal secession and patterns of natural disturbance (*i.e.* flood/burn cycles), their condition is also a result of management activities that maintain a given wetland in a distinct successional state, for whatever purpose. Wetlands used for duck hunting are flooded and drained periodically to maintain large areas of open water by limiting the growth of emergents. More often they are sprayed with aquatic herbicides. Wildlife refuge managers use similar techniques to thin out invasive plant species, attract migrating waterfowl or enhance fishery production. In most cases, the management objective is defined before the wetland is assessed and according to the method used to assess it, which results in selective management priorities that promote one function at the cost of more complex interactions between physical, chemical and biological constituents. Arguably, these management strategies engender uniformity in wetland design, which can have considerable impacts on wetland condition. As a consequence, the overlap found in a comparison of these approaches between how hydrology contributes to habitat and how habitat, in turn, contributes to hydrology is overlooked and the benefits of restoring these ecosystems cannot be adequately realized.

For both the Phase I and Phase II studies, the HGM classification scheme proved to be insufficient because the distinctions between the present hydrological states of wetlands in such a highly disturbed floodplain would be skewed by the historical circumstances of the Missouri River (*i.e.* channelization and impoundment). Cowardin *et al.* (1979), at the class level, describes ecological differences between wetlands possessing similar hydrogeomorphic attributes.

3.3 Wetland classes

Cowardin *et al.* (1979) describes three main classes of wetland systems: emergent, aquatic bed, and unconsolidated bottom. These three classes appear in the Cowardin classification scheme under both palustrine and lacustrine system-headings. Each of these classes describes a relatively homogeneous wetland. Wetlands with uniform physical characteristics are easy to classify, yet they might behave differently than wetlands with non-uniform characteristics. To account for the occurrence of wetlands containing a combination of features and a wide range of depths found during this study, a fourth class was created: unconsolidated emergent aquatic bed or “mixed” wetlands. Example photos are in Appendix C and definitions of reclassified wetlands are as follows:

Palustrine Aquatic Bed (PAB) wetlands are dominated by floating/submerged aquatic plants (hydrophytes) and deepwater emergents that require permanent surface water or consistent flooding for optimum growth. Bermed or dyked versions of these wetlands have artificially steep relief in littoral zones, which limits habitat for shallow-water emergents and geophytes.

Palustrine Unconsolidated Bottom (PUB) systems are relatively shallow wetlands in open areas with less than 30% emergent vegetation that are characterized by the lack of large stable surfaces for plant and animal attachment. They are susceptible to wind action, which causes sediment resuspension, substrate instability and light limitation. Such wetlands can also result from management practices that favor specific uses, including duck hunting and fishing.

Palustrine Emergent (PEM) wetlands are characterized by rooted herbaceous hydrophytes, helophytes, phanerophytes and geophytes. They are permanently or intermittently flooded for most of the growing season, mostly vegetated (lacking open-water areas) and generally too shallow to house dominant deepwater hydrophyte communities.

Palustrine Unconsolidated Emergent Aquatic Bed (MIX) wetlands tend to exhibit equivalent proportions of each class (~30%) or are evidently susceptible to climate extremes (*i.e.* flooding or drought), which can cause them to vacillate between dominant classes.

IV. Floodplain Wetland Disturbance Assessment

4.1 Past endeavors

The purpose of the Wetland Disturbance Assessment is to subjectively estimate the environmental impact of human activities on wetland ecosystems using readily observable assessment parameters. This approach evolved from knowledge of past and current wetland rapid assessment methods (Mack 2001; Sutula *et al.* 2006) as well as our earlier attempts to quantify disturbance/reference buffers using the 2004 US Fish and Wildlife Service's National Wetlands Inventory (NWI) polygons and 2002 National Land Cover Datasets (NLCD). One of the main challenges to developing rapid assessment tools has been the characterization of reference conditions as "least disturbed" according to the concepts outlined in Stoddard *et al.* 2006.

Beury *et al.* 2008 and Kriz *et al.* 2007 experimented with a GIS-based analysis of land use surrounding NWI wetland polygons. The zonal statistics tool in ArcGIS was used to characterize the land use within 250m of the wetland perimeter. The land use (as published in the National Land Cover Dataset, NLCD 2002) surrounding each wetland was characterized as disturbed or undisturbed and given a corresponding reference value of zero or one. Results of this approach were inconclusive.

Houlahan and Findlay (2004) suggest the critical distance at which adjacent land-use degrades wetland water and sediment quality can extend from 2000-4000m (in more pristine wetlands). Beury *et al.* (2008) examined relationships between land use compositions derived from greater buffer widths (1000m, and 2000m), but results were not significantly different when compared to the narrower buffers (250m). Use of a “reference buffer” for wetlands in the CPCB Regional Wetlands Database could not adequately define “reference” condition for known disturbance-related response variables (Figure 3). Hence, land use and land cover buffers defined by NWI wetland polygons do not seem to be related to wetland water quality.

Because wetland classes are used to categorize wetlands of similar physiological attributes (*i.e.* depth, substrate stability and function), they also reveal something about each class’ potential reference state (*e.g.* least disturbed condition). A refined and calibrated disturbance assessment can indicate an individual wetland’s state-of-disturbance (conditionally) in reference to what it could be (potentially). Some disturbance metrics may affect all classes at the same magnitude while others will need to be weighed according to the physiological attributes and ecological sensitivity of distinct wetland classes. A Disturbance Assessment in the form of a rapid assessment method combined with a relevant classification scheme may offer a more “grounded” approach to quantifying disturbance in wetlands because it is able to account for ecological integrity in the context of human settlements that constantly interact with the natural environment.

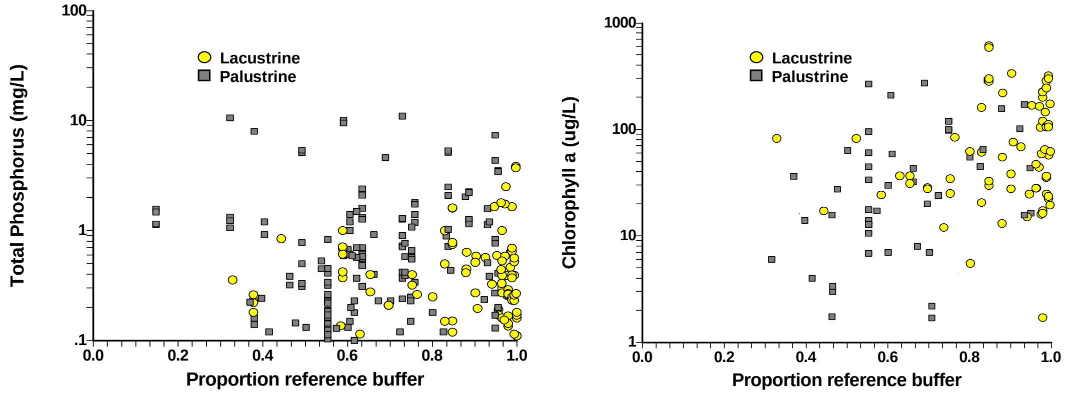

Figure 3: Total phosphorous and chlorophyll *a* vs. reference buffer with data from the Regional Wetlands Database. Originally we considered a reference buffer value ≥ .70 as indicative of potential least or minimally disturbed. The absence of clusters among "lacustrine" and "palustrine" wetland types suggests that there are no significant differences between the groups. Additionally, reference buffers plotted against known disturbance-related variables do not seem to be related to one another, so reference buffers may be poor indicators of disturbance in wetlands.

To define wetland condition, it was necessary to establish a conceptual basis for describing a "reference" state (Stoddard et *al.* 2006) and to reconcile the tension between allegedly conflicting notions of function and condition. The link between function and condition lies in the assumption that ecological integrity is an integrating "super-function" of wetlands. If condition is excellent (*i.e.* equal to reference condition), then the functions of that wetland type will also occur at reference levels (Fennessy *et al.* 2004). Reference conditions for wetlands vary as a result of regional characteristics, physical differences between wetland types and degrees of human interference. This interference can occur directly, through physical alteration of wetland ecosystems, or indirectly through adjacent land-use practices. Similarly, it is common for wetland rapid assessment methods to define impairment as visible human impacts on wetland hydrology (Mack 2001; Sutula *et al.* 2006).

4.2 The assessment

After considering several reviews of wetland rapid assessment methods (Fennessy *et al.* 2004; Fennessy *et al.* 2007; Innis *et al*. 2000), the Ohio Rapid Assessment Method (Mack 2001) and the California Rapid Assessment Method (Sutula *et al*. 2006) were used in designing the Missouri River Floodplain Wetland Disturbance Assessment. While the California and Ohio methods attempt to provide a more or less comprehensive evaluation of wetland rapid assessment parameters, the Disturbance Assessment developed for this study focuses on *Wetland Attributes, Reference Indicators, and Disturbance.*

Wetland Attributes are used to score how well-equipped the wetland is able to deal with disturbance (or how it is currently dealing with it), *Reference Indicators* are those characteristics that would demonstrate barriers to human disturbance (*e.g.* laws) or otherwise indicate pristine conditions for wildlife or hydrologic interaction in the landscape, and *Disturbance* is defined as evident physical perturbations or known observable impairments that may occur as a result of them, such as excessive sedimentation and/or altered hydrology. Although some overlap between assessment metrics was inevitable, care was taken to avoid redundancies in scoring. Metrics dealing directly with the classification scheme used in this study (*i.e.* depth and the temporal dimension of inundation) were also left out. Finally, metrics pertaining to the water and floristic quality response variables measured in the field that deal with known ecological impacts of disturbance were limited so as not to adversely affect a comparison with data from a Floristic Quality Assessment.

The resulting assessment method is advantageous in the sense that it is a subjective scoring process in which the "subject" is evaluating human impacts without being asked to make specific judgments about the more technical aspects of wetland ecological integrity. Though the three sections in the Disturbance Assessment are meant to be used together as a combined score calculated by adding attribute scores to reference scores and then subtracting disturbance, each section's score on its own may also be useful in describing certain wetland characteristics or trends in wetland condition.

Table 1: List of assessment parameters used in quantifying disturbance. Wetland Attributes are scored up to 3 pts each, and Reference and Disturbance parameters ±1 pt. See Appendix E for field sheet used in scoring.

Wetland Disturbance Assessment Parameters		
Wetland Attributes	**Reference**	**Disturbance**
Size (acres) *Buffer Width (m)* *Surrounding Land Use* *Hydrology (Water Source)* *Vegetation Coverage*	*Legal Protection* *Amphibian Habitat* *Waterfowl Habitat* *Endangered/Threatened Species* *Interspersion* *Connectivity*	*Sedimentation* *Upland Soil Disturbance* *Presence of Cattle* *Excessive Algae* *>25% Invasive Plants* *Steep Shore Relief* *Altered Hydrology* *Management*

4.2.1 Wetland Attributes

Wetland size classes (<25 acres, 25-50 acres and >50 acres) were determined with consideration for the high fragmentation of landscape in the Missouri River floodplain and also from what other rapid assessment methods (*e.g.*, the Ohio Rapid Assessment Method) gauged as appropriately "large" wetlands.

Natural buffer-width or thickness was an important metric according to several assessment methods. Natural buffers are thought to provide protection against local disturbances.

Surrounding land use is defined as intensive, recovering, undisturbed or a mixture of intensive and undisturbed (scored the same as "recovering" landscape). Row crops, grazed pasture, residential areas and/or industrial complexes that are visible in land immediately adjacent to the study area are considered intensive uses. Natural buffer should be considered part of the surrounding land in the 'undisturbed' category.

Hydrology can be an indicator of wetland class and vary independently of human disturbance. However, in the context of assessing human disturbance and in some respect functionality in the landscape (in terms of connectivity), different hydrological variables were scored according to the wetlands' water source in a general sense. For wetlands within the floodplain of a large river, it is unlikely that solely precipitation-fed wetlands would be a natural occurrence; rather they would be a result of artificial manipulation of historical hydrologic regimes. Assuming the most historically functional and minimally disturbed condition for a floodplain wetland is to receive and discharge flowing water, then it is a question of how 'disturbed' the inflowing water appears to be. Wetlands develop rapidly with a continual (or seasonal) inflow of river water (or overland flow), which maintains steady propagule/organism inflow and allows for mixing of basins during river floods, a process known as 'self-design' (Mitsch *et al.* 1998). Therefore, the most natural and constant inflowing alluvial water source receives the highest score, wherein less natural sources, such as stormwater drains or channelized ditches receive an intermediate score.

Vegetation coverage below 20% is indicative of a disturbed wetland, a wetland that is less capable of dealing with disturbance or one that isn't dealing with it very well. Coverage of over 70% reduces the potential for habitat diversity, so receives an intermediate score. Finally, 40-70% coverage was thought to be ideal for floodplain wetlands because a moderate amount of vegetation coverage suggests a high occurrence of edge habitat between open water and vegetated areas, providing for a diversity of habitats.

4.2.2 Reference Indicators

Indicators of reference conditions refer to the absence of human disturbance within the wetland. Metrics that reflect undisturbed ecological condition can be combined for a condition score used to track the status of a site. Reference indicators are a combination of factors that impede human disturbance or indicate the presence of valuable wetland features or “value-added metrics” (Fennessey *et al.* 2007). The inclusion of reference indicators was necessary to factor in qualities that were not as quantifiable as those evaluated in the Wetland Attributes section, meaning they could not be scored on a low to high scale and were better evaluated in their presence or absence.

Protected wetlands deter certain types of human disturbance over time, thereby increasing the probability that the wetland experiences relatively little disturbance (except for management, which is discussed in the next section).

Evidence that *waterfowl* and/or *amphibians* are present or would be present during the migratory season, suggests the wetland is capable of providing wildlife habitat, including food and nesting cover.

Endangered or Threatened Species warrant further protection of the area under federal laws and would thus generally discourage disturbance.

Interspersion (Mack 2001) refers to natural non-uniformity in wetland habitat design. Several native wetland fauna require multiple habitat-types. If these habitat-types are not in close proximity to one another, or interspersed throughout the wetland area, then it may be difficult for such fauna to survive. The assumption here is that between two wetlands of the same size with the same proportions of open-water to vegetated habitat, the one with a more 'mixed up' habitat occurrence would be more successful at supporting native wetland biodiversity and therefore in more of a 'reference' state.

Connectivity refers to an individual wetland's interaction with the landscape and associated hydrologic features. Features that disrupt connectivity like levees, berms or other water structures, can be easily identified and would indicate disruptions to historical hydrologic regimes. This assumes most floodplain wetlands were originally connected to the river or that water was able to cycle through them intermittently.

4.2.3 Disturbance

Metrics that indicate human disturbances known to degrade wetland health are listed in this section of the Disturbance Assessment. For each disturbance a point is subtracted. If the disturbance is unusually severe or at a high rate of occurrence, then more than one point can be subtracted.

Sedimentation is a natural process for many wetlands in the Missouri River floodplain. Yet, evidence of excessive sedimentation (observed as plumes or fresh deposits within wetlands) can dramatically affect the structure and function of wetlands.

Upland soil disturbance or tillage in the immediate area drained by the wetland is scored separately as a local disturbance that demonstrates the potential for excessive sedimentation, although it may not be observable at the time of evaluation.

The *presence of cattle* is not considered a natural occurrence, even in circumstances where the cattle graze the wetland periodically throughout the year.

Excessive algae usually suggest that there is an imbalance within an aquatic ecosystem (*i.e.* excessive nutrients or eutrophication). Regardless of whether the cause has to do with fertilizer run-off, sediment resuspension or cattle, the presence of excessive algae impedes the growth of aquatic/emergent plant life and threatens the survival of some aquatic organisms.

Over 25% invasive species had to arrive at the wetland through one channel of disturbance and be allowed to proliferate, either as a result of degraded wetland conditions that favored their growth over native species or because hydraulic alterations, excessive disturbance and/or misguided management practices.

Steep shore relief is a common occurrence in wetlands 'designed' for preservation during the last few decades of the 20th century. Several of these wetlands exhibit a uniform depth and, although they cover a large area (sometimes several hundred or thousand acres), the wetland has very little shore relief. In nature, a high shore length to surface area ratio and gradual relief in littoral zones would likely characterize floodplain wetlands in the Midwestern US. The morphological uniformity of several previously designed or preserved systems may favor invasive species and decrease biodiversity.

Hydrologic alterations that deviate from the historical flow regime in a manner that appears to have severed the ties between the wetland and its surrounding landscape are distinct from hydrologic alterations that demonstrate a concern for connectivity by attempting to reconnect the wetland or preserve the historical regime.

Management for specific purposes, such as hunting, fishing or wildlife preservation results in systems that are already disconnected at the conceptual level as well as the physical level with respect to their intrinsic properties as potentially undisturbed wetlands, which may lead to low quality systems. Management practices can be observed at particular wetland sites and their objectives confirmed by conversations with the landowners or designated managers.

V. Field and Lab Techniques

5.1 Water chemistry

Each wetland site was sampled once during the project. Three 1L samples were collected at equal distances from the longest axis of the dominant habitat type (open-water or vegetated) and combined into a composite sample. A transect-based point sampling regime was used to determine the locations of three water samples to be collected from each wetland (Figure 4). Five depth measurements were taken along each of three equally spaced transects that are perpendicular to a longitudinal transect that bisects the wetland along its longest width. The measurements begin and end one meter from the shoreline.

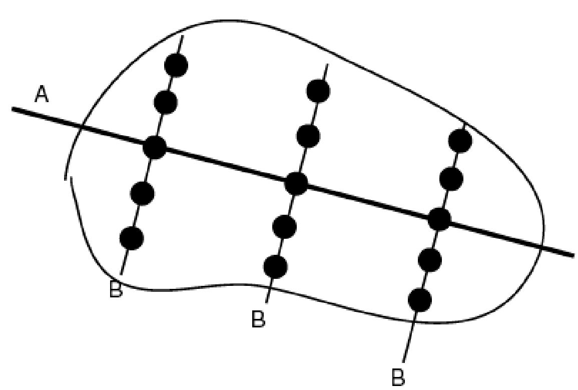

Figure 4. Transect-based point sampling regime indicating the longitudinal transect (A) of the wetland and three equally spaced perpendicular transects (B). Depth measuements will be taken at five points (•) along each perpendicular transect. Water samples and in situ meansurements will be taken at each transect of A and B.

Before leaving each site, 50-100 mL of the composite sample were filtered for chlorophyll a and placed into a labeled vial, a separate sample was preserved for total organic carbon in a 125 mL bottle spiked with 85% phosphoric acid and two brown glass 1-L amber bottles were filled with raw water. Containers were stored on ice and shipped to the KBS Ecotoxicology Lab within 48–72 hours from time of collection for analysis of total nitrogen, total phosphorus, soluble reactive phosphorus, nitrate, nitrite, ammonia, herbicides and chlorophyll a using Standard Methods (21^{st} ed) (APHA 2005) unless otherwise specified. Within seven days of the sampling date, raw samples were filtered and preserved in the lab for dissolved organic carbon and filtered and extracted for herbicide analysis. Appendix E lists the forms/instruments/procedures used for *in situ* and laboratory measurements. Accuracy and precision for each analytical technique are as listed in Standard Methods. *In situ* measurements of pH, dissolved oxygen, turbidity, conductivity, air and water temperatures, and salinity (by calculation) were obtained at each sample collection point using a laboratory-calibrated Horiba® U-10 Multiparameter Water Quality Checker. Secchi transparency was also recorded and photos taken. An alternate grab-sample and *in situ* suite of measurements were collected for subdominant habitat types, if there was sufficient observable evidence to suggest that the characteristics might deviate from or distort the composite sample (*i.e.* from open water segment when main segment was vegetated or vice versa).

5.2 Floristic quality assessment (FQA)

A field botanist accompanied the wetland crew to perform vegetation surveys. FQA is a standardized tool used for estimating the floristic quality, and by extension, the overall ecological quality of a natural area based on the vascular plants growing there. FQA is based on calculating an average coefficient of conservatism (C) and a floristic quality index (FQI) for a site of interest. Coefficients of conservatism express two basic ecological tenets: plants differ in their tolerance of disturbance type, frequency, and amplitude, and vary in their fidelity with remnant habitats (Taft et al. 1997). Coefficients are available for vascular plants in each of the four states in the study area (Freeman 2002, Ladd 1993, Steinauer 2002).

Observer bias is controlled by employing a single field crew each year and collection of field data was limited to the 3-month period from mid-June to mid-August to help control phenological bias and ensure that vegetation reaches maturity as flowers, seeds and fruit are often needed to correctly identify some plant taxa. Floristic metrics include total species richness (presence/absence), native species richness (presence/absence), % of non-native species, mean conservatism (all species), mean conservatism (native species only), floristic quality index (all species), floristic quality index (native species only), and number of state-rare species. Floristic data were analyzed using appropriate multivariate statistical techniques (including cluster analysis, principal components analysis, and two-way indicator species analysis).

VI. Results

6.1 Regional variables affecting wetland water and floristic quality

All data from Phase I and II were combined into a single database. The first round of analyses was done according to regional groupings within the study area (*i.e.* lower, middle and upper). Because of similarities between the lower and middle groups relative to the upper group and the low occurrence of target sites in the lower reach, the lower and middle sites were pooled into a new "lower" group. This regrouping was further supported by the site distribution within Omernik Level III ecoregions; principally between the western cornbelt and central irregular plains (Figure 5).

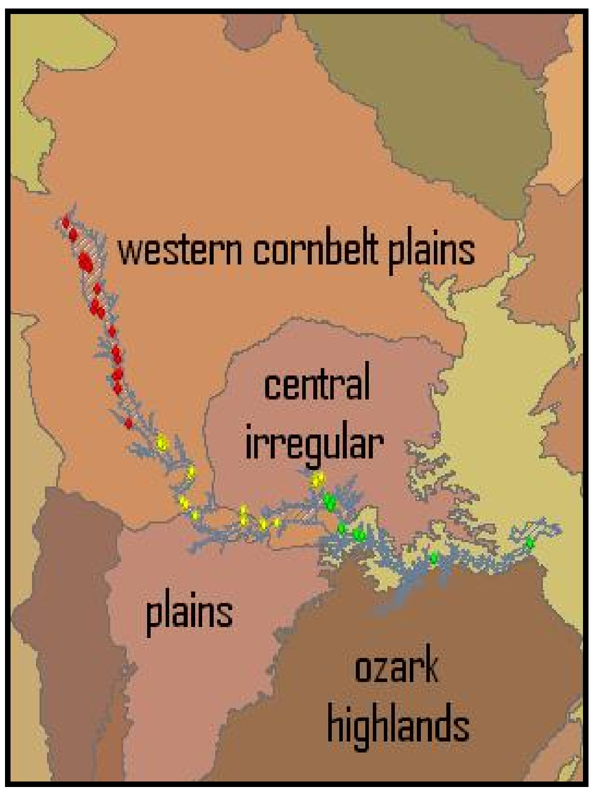

Figure 5: Reach distribution by ecoregion. Red = upper: Sioux City, IA to St. Joseph, MO; yellow = middle: St. Joseph to Columbia, MO; green = lower: Colombia to St. Louis, MO.

Hydrogeological differences between the lower and upper regroupings are also relevant. The floodplain is much wider in the upper reach than in the middle and lower reaches. Conductivity and TN:TP ratios show a significant separation between regrouped lower and upper regions (Figure 6).

Generally, sites in the original lower reach appeared to be the most disturbed, followed by the upper and middle reaches. This trend is supported by the results of the site-selection process in which the original lower reach showed the highest occurrence of non-target sites, relative the upper and middle reaches. An unbiased, randomized method to detect wetlands was employed in all three reaches, so a higher occurrence of non-target sites in one region suggests there were a smaller proportion of actual wetlands within the population of potential wetland sites (see Section II). The original lower reach also tended to score lowest with respect to overall floristic richness and floristic quality, which is consistent with relative differences in disturbance between all three reaches. To account for the influence of environmental heterogeneity on major water quality variables and to replace the somewhat arbitrary spatial groupings with more environmentally related groupings, the original lower and middle reaches will herein be referred to as the lower reach.

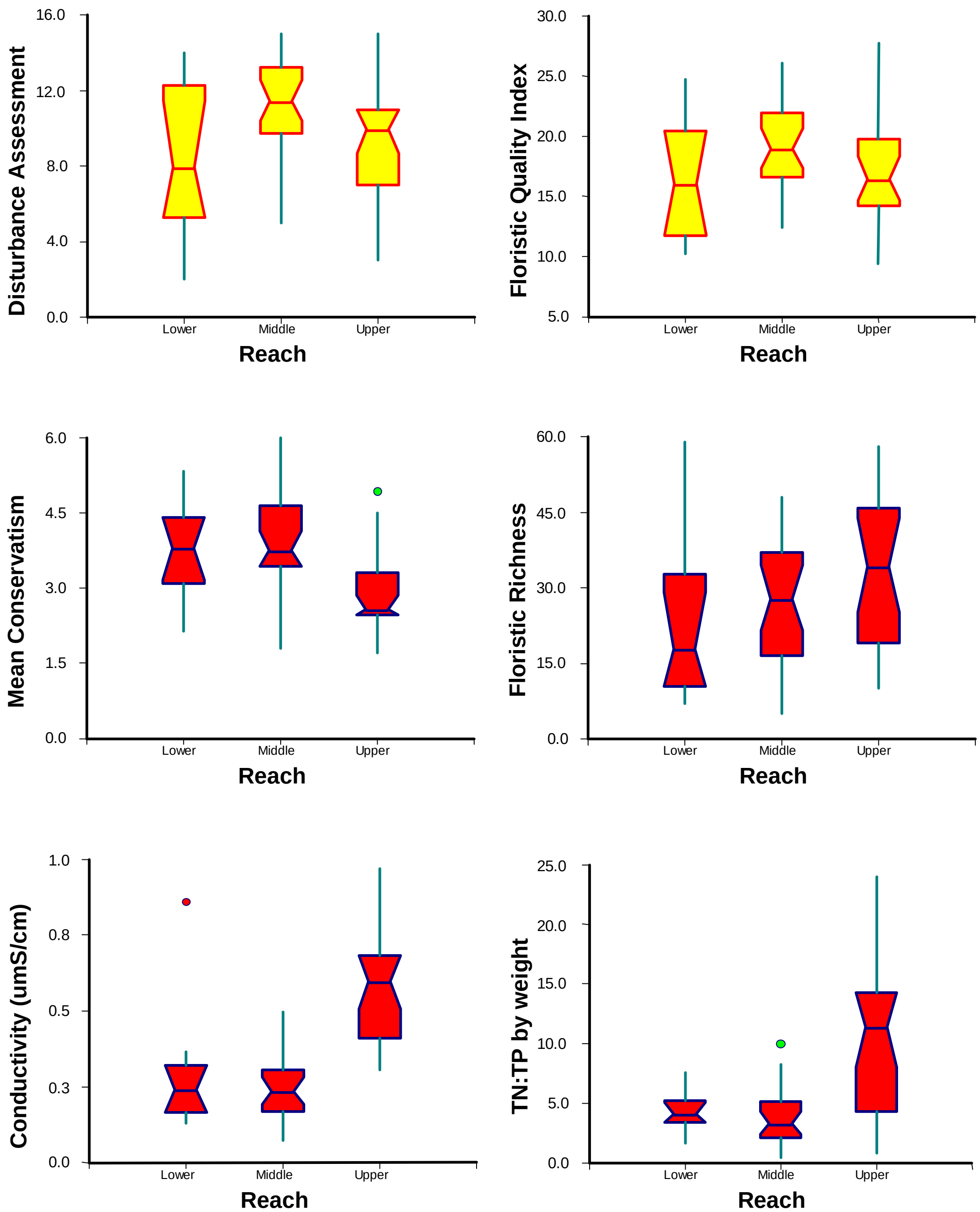

Figure 6: Box plots of selected disturbance, floristic quality and water quality variables for each of the three Missouri River floodplain reaches (*i.e.* Lower, Middle, Upper). Yellow plots denote statistically significant differences at $p < 0.10$ and red plots, at $p < 0.05$.

Besides major regional differences in conductivity and TN:TP ratios ($p < 0.001$, GLM ANOVA), further separations were found between the pooled upper and lower reaches with respect to pH, NH_3-N and total P ($p = 0.023$, 0.016 and 0.002) using Kuskal-Wallis one-way analysis of variance (ANOVA; NCSS 2004). The upper reach was deeper, showed higher pH, higher concentrations of NH_3-N and lower concentrations of total P (Figure 7).

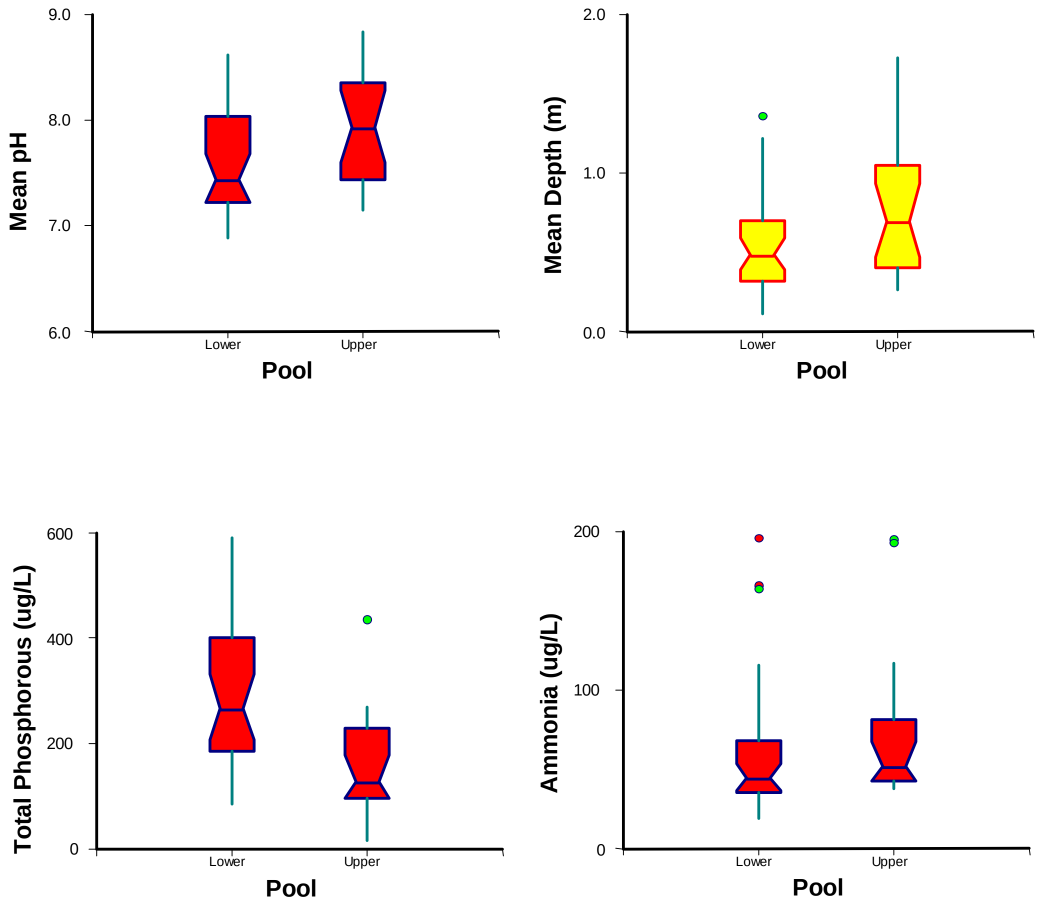

Figure 7: Box plots of water quality measurements between pooled upper and lower reaches. Yellow at $p < 0.10$ and red plots, at $p < 0.05$

Although there were no significant differences between the upper and lower pools for the FQI score and percent adventive vegetation, the upper pool exhibited higher richness and lower mean conservatism ($p = 0.019$ and 0.000 respectively) than the lower reach, which suggests the plant communities in the upper pool were normally higher in floristic richness, but lower in quality in terms of rareness and fidelity (conservatism). Trends in floristic quality components between the upper and lower pools may be coincidental; however there seem to be clear differences between water quality variables. The *less* significant ($p < 0.10$) difference in mean depths between the regions is consistent with differences in water quality.

6.2 Comparison of assessment tools

To verify the three main assessment tools used in this study, relationships between the CPCB wetland reclassification scheme, Disturbance Assessment (DA) and the Floristic Quality Assessment (FQA) were examined graphically (scatter/box plots) and statistically (regression) using Microsoft Excel and NCSS 2004. When considering all wetland classes, there appeared to be a statistically significant positive association between the DA and Floristic Quality Index (FQI) ($r = 0.42$; $p = 0.0009$; $f = 12.3$). More general trends in wetland class attributes can be observed in both the floristic richness and FQI in their response to DA scores (Figure 8).

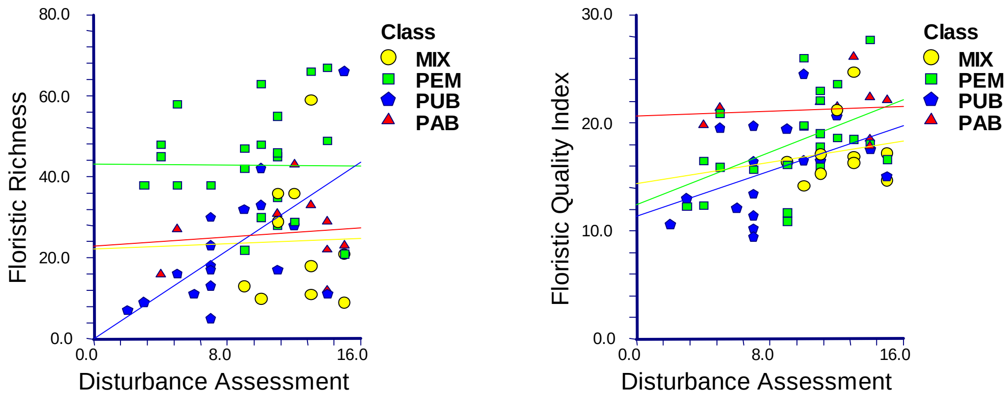

Figure 8: Scatter plots of floristic richness and floristic quality index versus disturbance assessment score (higher score = less disturbed); showing trend lines for each wetland class.

A comparison of scatter plots showing a floristic quality component (floristic richness - left) and the composite FQI (right) demonstrate the tendency of the FQI to normalize wetlands among classes and regions, whereas richness vs. disturbance show groupings that may be unique to floristic trends for specific wetland classes. As a predictor of floristic quality, the Disturbance Assessment may be underdeveloped with respect to how the impacts of disturbance types were quantified (*e.g.* internal vs. external). The DA was set up with certain assumptions made according to what degrades wetland condition and did not attempt to weigh disturbance types according to varying degrees of environmental impact, as such weights would have to be selected arbitrarily. Both the observations made by the DA and its assumptions can be tested; together with floodplain wetland classification, floristic quality and water chemistry.

6.2.1 Differences between wetland classes

The Kruskal-Wallis one-way test for analysis of variance (ANOVA) and Duncan's Multiple-Comparison Test (NCSS 2004) showed groupings by certain wetland classes for disturbance and floristic quality variables (Table 2; Figure 9). Statistically significant differences were found for DA scores between unconsolidated bottom (PUB) and mixed classes ($p = 0.015$), with the PUB class as most disturbed. For floristic richness, the emergent class (PEM) separated from aquatic bed (PAB), mixed and PUB classes ($p = 0.0001$).

Table 2: Differences by class ($p < 0.05$) from Kruskal-Wallis one-way analysis of variance and Duncan's Multiple-Comparison Test (NCSS 2004). Classes shown in the table vary significantly from those shown in the left column according to the variable above. Variables that showed no significant differences between classes are not displayed.

	Disturbance Assessment	**Floristic Richness**	**Percent Adventive**	**Mean Conservatism**	**Floristic Quality Index**	**Mean Depth**	**Mean Conductivity**	**Mean Turbidity**	**Chlorophyll a**	**Total Organic Carbon**
Emergent PEM		PAB MIX PUB	PAB MIX	PAB MIX PUB		PAB	PAB		MIX	PAB PUB
Aquatic Bed PAB		PEM	PEM	PEM	MIX PUB	PEM	PEM	MIX	MIX	MIX PEM
Uncons Bottom PUB	MIX	PEM		PEM	PAB					MIX PEM
MIX	PUB	PEM	PEM	PEM	PAB			PAB	PEM PAB	PAB PUB

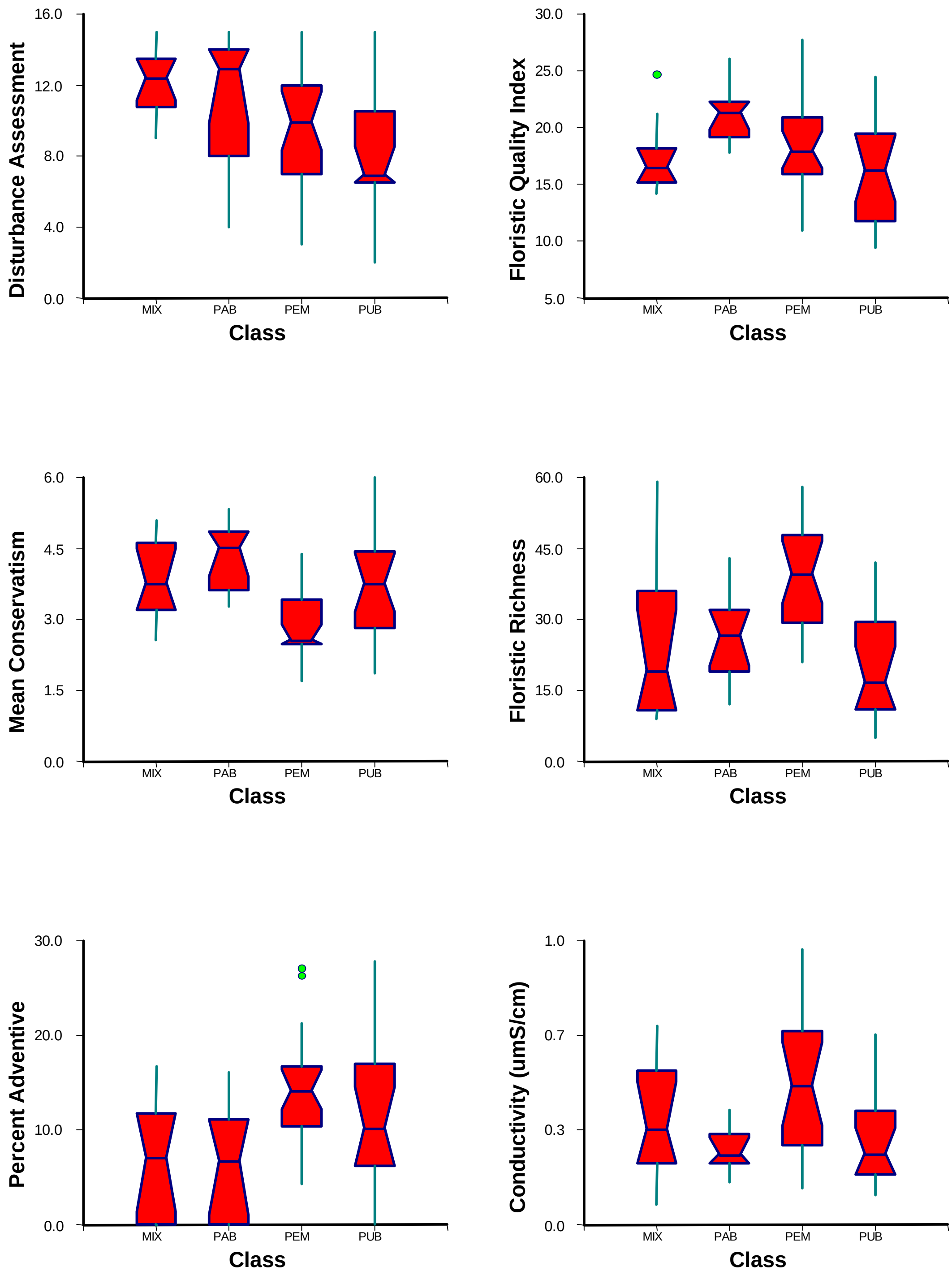

Figure 9: Box plots of floristic quality variables grouped by class. All box plots showed statistically significant differences ($p < 0.05$) between one or more variables.

Palustrine Emergent (PEM) wetlands are distinct with respect to floristic quality and some structural and water quality variables (*e.g.* mean depth and conductivity). They tend to be higher in species richness and lower in mean conservatism across a wider range of disturbance and were also found to contain more invasive plant species than PAB or mixed wetlands ($p = 0.008$), which is consistent with other trends in floristic quality as invasive species and would simultaneously increase richness and decrease conservatism. Alternatively, mean conservatism was higher for aquatic bed and mixed wetlands than for emergent wetlands ($p = 0.0003$).
Mean conductivity was much higher in PEM wetlands (0.491 umS/cm) than in PAB wetlands (0.265 umS/cm), which could be a result of characteristically shallower depths and higher rates of evapotranspiration. Alternatively, PEM and PAB wetlands had less phytoplankton (*i.e.* chlorophyll *a* concentrations) than mixed wetlands perhaps as a consequence of competition between emergent/aquatic vegetation and algal growth.

Palustrine Aquatic Bed (PAB) wetlands separated from PEM wetlands in most cases (except for chlorophyll *a* concentrations) and had less turbidity than mixed wetlands. Aside from receiving higher FQI scores than PUB wetlands and mixed wetlands ($p = 0.007$), PAB wetlands grouped with PUB wetlands in having higher total organic carbon concentrations compared with PEM and mixed classes. PAB wetlands exhibit high floristic quality relative to other wetlands and were found to be the rarest of the sample population.

Palustrine Unconsolidated Emergent Aquatic Bed (MIX) wetlands as a group were less disturbed than PUB wetlands according to the disturbance assessment and had lower FQI scores than PAB wetlands. These wetlands were more turbid than PAB wetlands and had higher chlorophyll *a* concentrations than either PAB or PEM wetlands. Like PAB wetlands, mixed wetlands did not separate from PUB wetlands in many cases pertaining to water and floristic quality; except that they were less disturbed and had less total organic carbon.

Palustrine Unconsolidated Bottom (PUB) wetlands were generally the most disturbed (according to the DA) and scored the lowest in floristic quality. For most water quality variables, PUB wetlands were not determined to be significantly different from other classes. Substrate composition or otherwise structural disturbances/limitations within the wetlands (*i.e.* internal factors) may hinder the growth of aquatic/emergent vegetation; thereby keeping these wetlands from developing into mixed, aquatic bed or emergent wetlands.

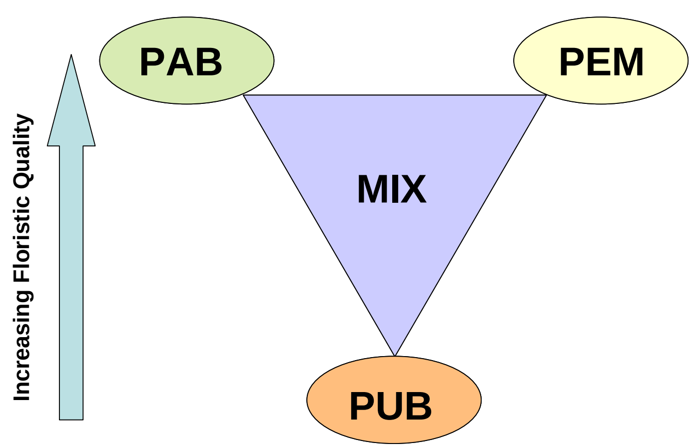

Figure 10: Diagram showing relationships between floodplain wetland classes on a gradient of floristic quality.

6.2.2 Floristic quality and disturbance

Kuskal-Wallis ANOVA and Duncan's Multiple Comparison Test were run with the upper, middle and lower thirds of the FQI scores, derived from the entire sample population. The upper third of FQI scores (> 19) grouped with a mean richness of 38 against the lower two-thirds, whereas the other differences were found between the lower third of FQI scores (< 16) and the upper two-thirds. The lower third of FQI scores had a mean DA score of 8 and the upper two-thirds had a mean DA score of 11. The lower third also had a higher percentage of invasive plants, lower conservatism, higher turbidity and higher dissolved oxygen (Figure 11). Irrespective of relationships involving the floristic components that go into calculating the FQI score, an FQI score of less than 16 may indicate that a wetland is impaired or experiencing high levels of disturbance related to sedimentation and/or eutrophication.

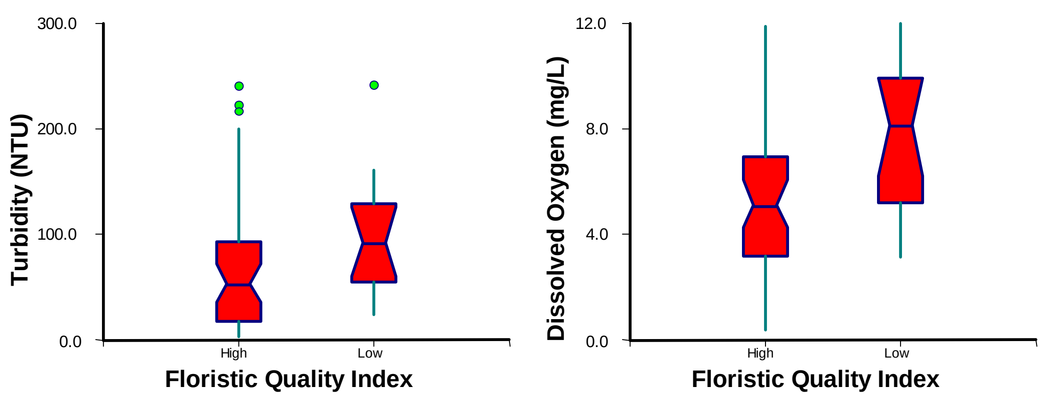

Figure 11: Box plots of water quality variables showing significant separation ($p < 0.05$) when grouped by lower third ("Low"; FQI < 16) and upper two-thirds ("High"; FQI > 16).

These findings suggest a relationship between disturbance and floristic quality. However, this relationship must be explored further, either because of uncertainties regarding the quantification of different regional, local and structural disturbances or because of the unique nature in which different wetland classes respond to them. So far, it is evident that the Disturbance Assessment and Floristic Quality Assessment should be adequate for evaluating more comprehensive aspects of wetland condition and may allow for broad comparisons among regions and wetland types.

Breaking the FQA into its components (*i.e.* mean conservatism, percent adventive and richness) revealed significant differences between wetland classes as well as between the upper and lower reaches of the study area. Moreover, the classification scheme used in this study also appears to be indicative of varying degrees of disturbance. Emergent wetlands endure a range of disturbance and exhibit distinct tendencies according to floristic quality components; whereas aquatic bed wetlands are deeper and mixed wetlands, with less uniform depth, would contain both aquatic and emergent vegetation communities.

To summarize, emergent, aquatic bed and mixed wetlands may be higher quality versions of unconsolidated bottom wetlands, a point that is emphasized by statistically significant differences in the DA score between PUB and MIX classes (Table 2). Aquatic bed and emergent classes are more homogenous habitats based on wetland structure (*e.g.* uniformity of depth). By contrast, mixed wetlands are less uniform in their ranges of depth than PUB wetlands. Therefore, the difference between the two might be accounted for by internal, more than surrounding disturbances. PAB and mixed wetlands also had higher FQI scores than PUB wetlands, indicating differences in floristic quality that are consistent with high levels of disturbance.

6.3 Characterization of least disturbed reference conditions

Using information from the disturbance assessment and floristic quality assessment, least disturbed, high quality wetlands were selected to characterize reference conditions for emergent, aquatic bed and mixed wetland classes. Palustrine unconsolidated bottom (PUB) wetlands were left out of the least disturbed reference characterization based on the assumption that they are physically degraded (or altered) versions of the other three classifications (see previous section). PUB wetlands were generally dominated by turbid open water and found to be susceptible to wind-action, sedimentation and drainage problems that may result from structural disturbance and the highly altered nature of the surrounding landscape. In addition, many wetlands in this class were managed to restrict the growth of emergent vegetation either through the use of herbicides or dredging based on physical evidence at the wetlands and landowner/manager comments. Because no emergent vegetation gets established, wind-action in shallower PUB wetlands facilitates sediment resuspension and favors the growth of algae. In addition, these wetlands would not be flooded/drained frequently enough to favor the growth of specific wetland vegetation. The intransient character of PUB wetlands sampled during this study appeared to result from direct human disturbance to the wetland and not from low recurrence flood events. In either case, this class of wetlands is a poor candidate for the characterization of least-disturbed wetlands, though they tend to exhibit some gradient of disturbance. With reduced disturbance and favorable management, PUB wetlands would likely develop into aquatic bed, emergent or mixed wetlands depending on their depth and degree of structural interspersion.

Disturbance Assessment scores, including individual reference and disturbance indicators, as well as floristic quality variables were considered in ranking least disturbed wetlands. The top three wetlands for each class (PEM, PAB, MIX) were determined within each regional pool (upper and lower) based on observable convergence in floristic quality variables and least disturbed conditions. There were few least disturbed candidates for the upper palustrine aquatic bed group relative to the sample population, and a low occurrence of aquatic bed and mixed wetlands throughout the study area relative to emergent and unconsolidated bottom wetlands (Figure 8). While the sample population for emergent wetlands does span different degrees of disturbance, the classes for mixed and aquatic bed wetlands were generally associated with higher floristic quality. As mentioned previously, degraded aquatic bed or mixed wetlands may exist, but would likely be classified as PUB wetlands, which suggests that aquatic bed and mixed classes may be less disturbed as distinct wetland classes. Finally, aquatic bed or mixed wetlands may be more sensitive to structural and localized disturbance than emergent wetlands, which appear to be resilient in retaining their class characteristics, even under highly disturbed conditions.

For the least-disturbed characterization, reference groups were analyzed by region and class in an attempt to highlight regional and structural characteristics that suggest optimum environmental conditions within wetlands and hydrologic functionality at landscape scales. In the following discussion, the responses of floristic quality metrics to measured water quality variables in least disturbed wetlands are compared to the entire sample population. Data tables for reference wetlands organized by class and reach are shown in Appendix D and variations between habitat types in Figure 9.

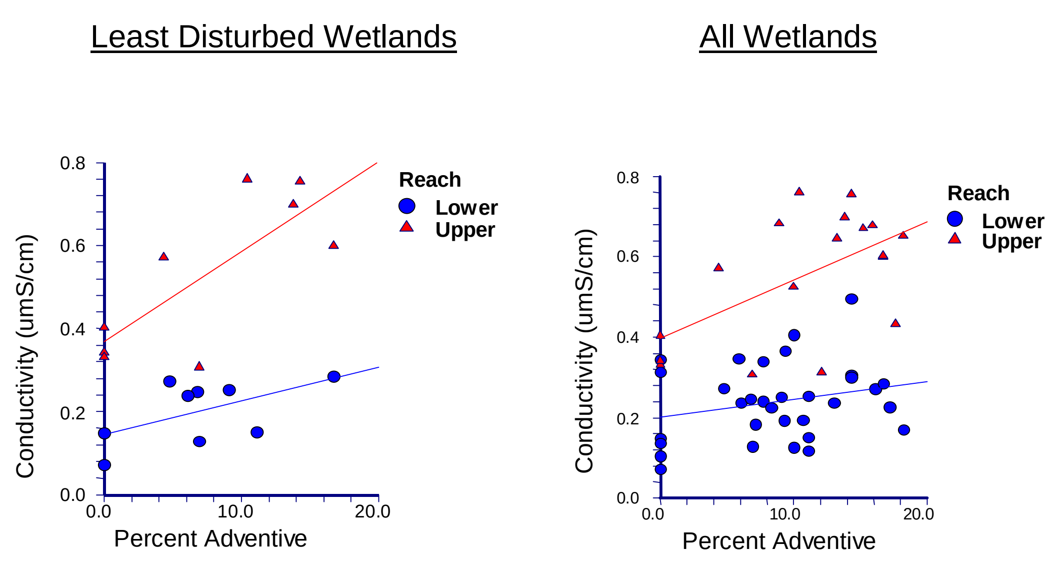

Figure 12: Scatter plots with trend lines for least disturbed wetlands grouped by reach in the left column and all wetlands sampled for water quality grouped by reach in the right column.

Differences in conductivity within wetlands were less than 0.01 umS/cm (Table 2). The upper reach of the study area had higher conductivity on average than the middle and lower reaches, which again justified pooling the middle and lower reaches for water quality analysis. Once pooled relative to what appears to be regional baselines for conductivity, relationships between conductivity, TN:TP and floristic quality variables became evident. High conductivity, relative to the regional baseline conditions, is associated with increased percentages of invasive plants. When applied to the entire sample population (including PUB wetlands) the trends are similar (Figure 12). Conductivity grouped by region, but also by class, between PAB and PEM wetlands (Table 2). High levels of conductivity indicate the presence of conductive ions in the water column, including metals and possibly some organic breakdown products. High conductivity may also reflect groundwater influence at regional scales, chemical contaminants at local scales or high rates of evaporation within more stagnant wetlands; where water becomes more concentrated (as in the differences between conductivity in emergent and aquatic bed wetlands shown in Table 2). This could result from disruptions to hydrology, which in turn would restrict water from flowing through the wetland and prevent it from being drained and replenished by seasonal or intermittent rains.

Total nitrogen and total phosphorous are more enduring measurements of nutrients in aquatic ecosystems. The relationship between them, the TN:TP ratio, is an important determinant for nutrient limitation. Usually, for lakes TN:TP ratios equal to or less than 10 indicates nitrogen is the limiting nutrient, values between 10 and 15 suggests co-limitation and above the 15-20 range, phosphorous is the limiting nutrient (although these ranges are currently being debated). Nitrogen sources are commonly from fertilizer, cattle or municipal waste. In the Midwest, phosphorous is normally associated with sedimentation and can be released into the water column from benthic sediment layers during periods of anoxia. TN:TP ratios are important to various species of vascular plants and algae, who have different requirements for amounts of N and P (Güswell and Koerselman 2002). Therefore, TN:TP was considered a regionally determined variable whose impact may vary depending on the wetland type (*i.e.* plant community structure). Like conductivity, TN:TP ratios could be associated with low conservatism, which suggests a higher occurrence of more tolerant plants as a secondary indicator of disturbance. The ratio also shows a positive association with floristic richness for emergent and aquatic bed wetlands, while richness in mixed wetlands may not be as sensitive to TN:TP ratios.

6.4 Water quality within individual wetlands

Samples for alternate habitat types (*i.e.* open water and vegetated) were also compared using Student's paired t-tests (NCSS 2004) to account for variation in water chemistry within wetlands (Table 3). Vegetated and open water samples were then grouped by sample type and tested for variance. Only dissolved oxygen showed statistically different groupings ($p = 0.042$) between the sample types with a mean of ~4 mg/L in open water and ~2 mg/L in vegetated areas. Comparing variation within and between wetlands helps to separate factors in terms of whether they are determined by structural, local or regional influences, though some are likely the result of all three. Conversely, for least-disturbed wetlands, DO levels were higher for emergent wetlands than for mixed or aquatic bed wetlands, which is discussed later in this section.

Table 3: Comparison of variation within individual wetlands according to differences in microclimates using paired t-test (NCSS 2004). Statistically significant differences between sample means are shown in bold (* = p < 0.10, ** = p< 0.05).

Means for open water vs. vegetated habitat types in seven wetlands		
	Mean Values	
Variables	Open Water	Vegetated
pH **	**7.33**	**6.91**
Conductivity (umS/cm)	0.271	0.268
Turbidity (NTUs)*	**69**	**23**
Dissolved Oxygen (mg/L) **	**3.96**	**2.95**
Temperature (^oC)*	**25.6**	**24.6**
Nitrate (mg/L)	0.01	0.02
Ammonia (ug/L)*	**67**	**103**
Total Nitrogen (mg/L)	0.92	1.25
Phosphate (ug/L) **	**109**	**179**
Total Phosphorous (ug/L)*	**299**	**640**
Chlorophyll a (ug/L)	25	75
Total Organic Carbon (mg/L)	10.4	16.1
TN:TP by weight **	**4.7**	**3.6**

Water and floristic quality in wetlands vary by region, wetland class, and hydrologic differences within wetlands. For Chipps *et al.* (2006) conductivity and TP were higher in more disturbed wetlands. For this study, least disturbed wetlands in different ecoregions were affected by baseline differences in conductivity and TN:TP ratios. Conductivity is associated with negative trends in floristic quality (richness, conservatism and invasive species) for all wetland classes. These effects vary by differences in plant community structure. Within wetlands, pH, dissolved oxygen, turbidity, temperature, ammonia, total and dissolved phosphorous, and TN:TP ratios show variations comparable to those found between wetland classes and at regional levels of analysis (Table 3).

Dissolved nitrogen in the form of nitrate was typically very low in wetlands. Low dissolved nitrogen suggests that biologically available nitrate is being used. Together with dissolved oxygen levels ranging from 2 to 6 mg/L on average, low nitrate levels are likely a result of denitrification processes. Furthermore, all wetlands were sampled during the day, when photosynthesis predominates in the water column. During the night and early morning, when respiration takes over, dissolved oxygen levels would be much lower and more nitrate would be consumed. Dissolved oxygen (DO) levels averaged around 2 mg/L in mixed wetlands, 4 mg/L in aquatic bed wetlands and 6 mg/L in emergent wetlands. DO levels also tend to vary by water depth and temperature. Dissolved oxygen levels are naturally lower in wetlands than in other aquatic ecosystems and most likely determined by structural variables before local disturbance or regional characteristics. Low DO levels may produce conditions favorable for dentrification, leading to low available nitrate in the short-term. Dissolved phosphorous (as phosphate) tended to vary within, between and among wetland types and regions, possibly resulting from immediate differences in wetland habitat structure, sediment resuspension and release from sediments under anoxic conditions.

For all wetlands, total nitrogen, turbidity and chlorophyll *a* were all positively correlated with one another (r = 0.53-0.77). Algae tend to consume nitrate quickly, so high concentrations of total nitrogen together with chlorophyll *a* suggest much of the total nitrogen found in wetlands is tied up in organic forms as algae or decaying plant matter. Algae tend to be favored by (and in turn contribute to) turbidity in the water column as they compete with emergent and aquatic plants in wetlands. With respect to least disturbed wetlands, the highest levels of chlorophyll *a* were found in the mixed class, averaging 86.2 ug/L in the lower and 127.8 ug/L in the upper reaches. Average chlorophyll a values for emergent and aquatic bed classes were much lower, ranging from 7.5 ug/L in upper aquatic bed wetlands to 33.3 ug/L in upper emergent wetlands (Appendix D). Turbidity and chlorophyll *a* were also found to be higher in unconsolidated bottom wetlands, which have been left out of the least disturbed characterization as impaired version of other wetlands. Depending on the wetland type, high levels of chlorophyll *a* may designate impaired conditions that inhibit or compete with the growth of vascular plants. Algae have a tendency to shade out vascular plants in wetlands with uniform depth and steep shores that are not drained often enough for less tolerant emergent plants to germinate. The combination of excess nutrients and turbidity is caused by erosion, agricultural runoff, hydrologic isolation (stagnation) and sediment resuspension via wind-action. Both mixed and PUB wetlands are commonly influenced by these characteristics, whereas the other two classes, PAB and PEM wetlands, seem to be more homogenous versions of wetland macrohabitats that dominate as a result of uniformity in wetland design. An ideal 'mixed' wetland would then be a combination of intermittently flooded PAB and PEM habitats with low turbidity in deeper, more permanent open water segments.

6.5 Overall condition of sample population

Building on the results from the site-selection process, the highest frequency of disturbance related to non-target, potentially historic wetland sites, occurred in the lower reach, then the middle and upper. Within the sample population, there were observed differences in disturbance at the regional scale (Figure 13) and by wetland class (Figure 14). Wetland condition is the result of multiple disturbances acting simultaneously. Even so, organizing wetland disturbances by region and class can only indicate the secondary nature of regional or class-specific trends, which are unable to fully account for the impacts of combined regional, surrounding and structural disturbances.

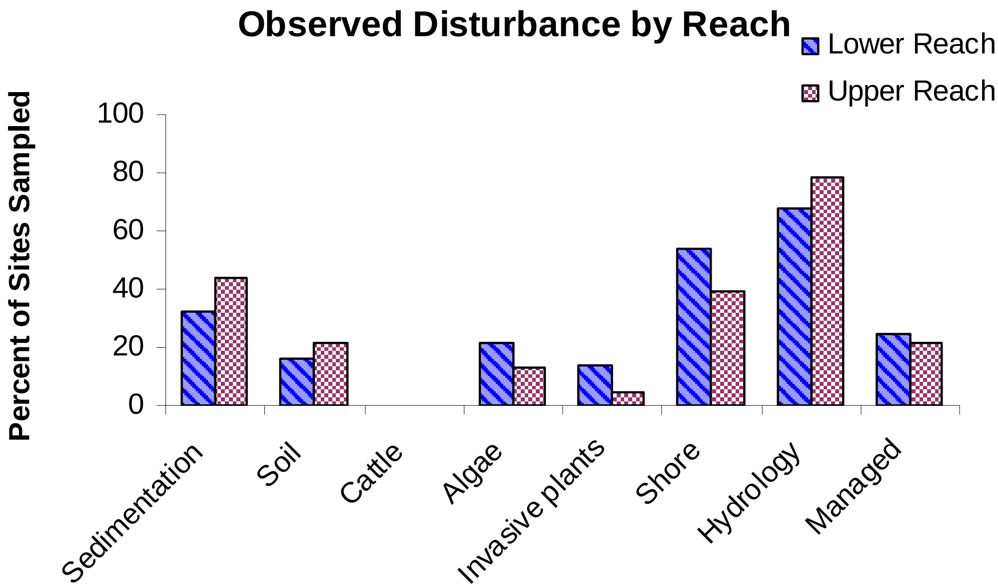

Figure 13: Types of disturbance by reach from Disturbance Assessment tallies.

Regional differences in disturbance were associated with lower levels of total phosphorous and higher levels of conductivity, TN:TP and ammonia in the upper reach. The upper reach also had higher floristic richness and lower mean conservatism. Because conductivity is non-specific in relation to what it actually measures (*i.e.* harmful herbicides *and* beneficial ions may both contribute to it), regional differences are only important to the extent that they must be considered when examining conductivity as an indicator of disturbance for multiple regions. In most cases, disturbance between regions did not vary by more than 10-15%, but showed similar trends that may ultimately be common to both regions. From disturbance assessment scores, floristic quality components and initial site-selection and ground-truthing, the lower reach appears to be more disturbed and of lower quality (floristically) than the upper reach.

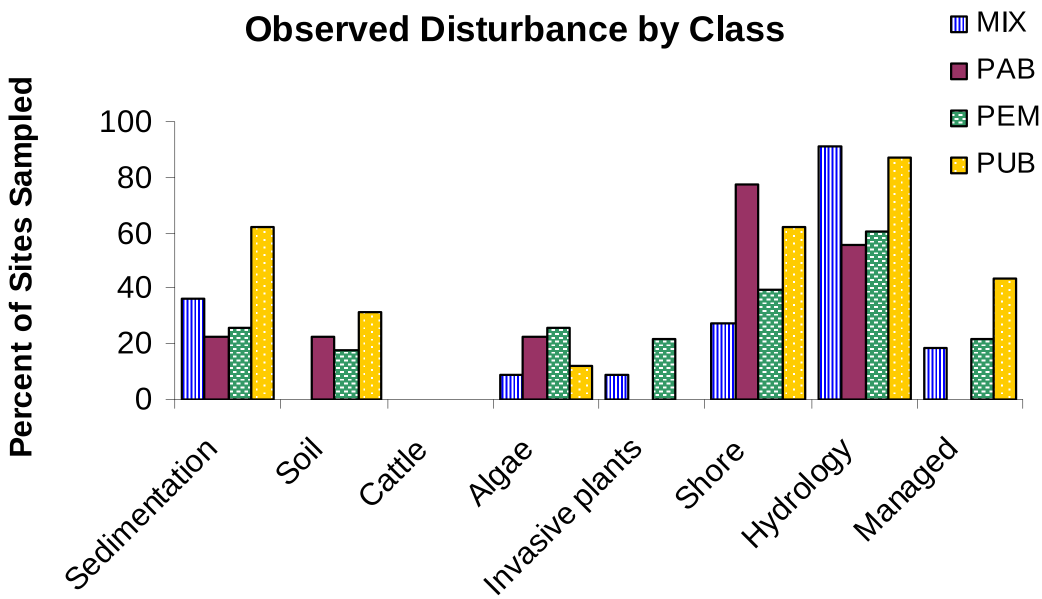

Figure 14: Types of disturbance by class from Disturbance Assessment tallies.

For all wetlands, the main types of disturbance had to do with sedimentation, upland soil disturbance, steep shores, hydrologic alterations and management. The upper reach showed a higher frequency of disturbance related to sedimentation and hydrology, whereas the lower showed slightly more disturbance in the form of steep shores and management.

Overall, PUB wetlands were the most disturbed and PAB wetlands were least disturbed. PEM wetlands spanned a range of disturbance whereas MIX wetlands were less disturbed than PUB wetlands and more disturbed than PAB wetlands and high quality PEM wetlands. The most common type of disturbance in the PAB wetlands was the presence of steep shores, followed by PUB, PEM, and MIX wetlands. A similar ranking might be achieved for uniformity in depth as it is determined by the way in which the wetland has been artificially contained within the landscape. The uniformity in the design of some wetlands is a fortunate occurrence in this study because it allows the characterization of homogenous wetland habitat types, or classes. Unfortunately, this uniformity is most likely a result of human disturbance. The condition of wetlands located within the Lower Missouri River floodplain is therefore highly disturbed, even in cases of least disturbed wetlands. For regional trends in disturbance, the site-selection process may the best indicator, whereas structural perturbations may have more to do with wetland classes, responses to localized disturbance and individual wetland conditions.

Wetlands were sampled during the years of 2005, 2008 and 2009. In terms of annual variations in weather, 2005 was dry, 2008 was wet and 2009 was average. 2005 was biased in selection of sites as a reference study. Meanwhile, significantly more sites were sampled in 2008 than in 2009, therefore no time-series analyses were done. In 2008 many of the sites visited appeared at high levels of disturbance as a result of flooding, which could have contributed to the large number of PUB and MIX wetland classes visited during that season.

6.6 Impact of disturbance types on wetland water and floristic quality

Wetlands are naturally equipped to deal with disturbance in the form of flooding and drought; however the question of how wetlands respond to human disturbance remains an important topic of discussion in the context of this condition assessment. The floodplain wetland Disturbance Assessment used in this study was designed to quantify human disturbance, *a priori*, based on the presence or absence of known disturbance and reference indicators as well as other physical attributes. One weakness of the current DA is its inability to adequately weigh different types of disturbance according to the magnitude of their impact on wetland condition.

ANOVA testing, followed by Multiple Comparison Tests revealed relationships between DA variable scores (presence/absence) and some measured wetland variables. Evidence of sedimentation within wetlands (22 affected, 37 not affected) was found to decrease floristic richness from a mean of 36 to a mean of 24 ($p = 0.005$) and FQI scores from 19 to 16 ($p = 0.003$). Conversely, evidence of upland tillage as surrounding disturbance showed no effect. For wetlands with steep shores, mean conservatism was found to decrease slightly ($p = 0.042$), but this was not verified by Duncan's Multi-Comparison Test. Meanwhile, alterations to hydrology appear to impact FQI scores, total N and chlorophyll a concentrations (Table 3). Other factors showed no statistically significant effects or were left out because they were already accounted for by response variables (*e.g.* vegetation coverage and >25% invasive species).

Table 4: Results of Duncan's Multiple-Comparison Test for altered vs. preserved hydrology in sample population (as defined in Section IV).

Differences in Hydrology		
	Altered *n = 38*	Preserved *n = 17*
FQI *p = 0.028*	17	20
TN *p = 0.042*	1.55 mg/L	1.09 mg/L
Chl *a* *p = 0.001*	53 ug/L	20 ug/L

Testing observations made by the DA was sufficient to begin categorization and characterization of disturbance types. Table 5 was constructed to show what type(s) of disturbances impact which variables. Wetland class is included as an internal disturbance because of the interplay between artificial internal/structural modifications and the observed wetland class. Results indicate that internal disturbance, described as structural disturbance (occurring within the wetland) and plant community structure (wetland class) are major determinants of water and floristic quality response variables measured during this study.

Further testing will be required to determine the extent to which each type of disturbance degrades wetland condition.

Table 5: Impacts of disturbance by type on various water and floristic quality variables. Variables impacted by disturbance types (columns) are marked with an "x" if that disturbance corresponds to the variable of the row in which the "x" appears. External disturbance types based on "Region" were derived from section 6.1 (Figs. 6 and 7). External disturbances characterized as "Local' were derived from section 6.3 during the reference discussion, to the extent that departure from reference conditions could be accounted for by local disturbances (see also Appendix D). For internal disturbances, marks in the "Structure" column came from section 6.4 (Table 3) and section 6.6 (Table 4) and "Class" distinctions, from section 6.2 (Table 2, Fig. 9). Some variables are affected by more than one disturbance type.

Impacts of Disturbance Types

	External		Internal	
Variables	**Region**	**Locality**	**Structure**	**Class**
Richness	x		x	x
Percent Adventive			x	x
Mean Conservatism	x		x	x
Floristic Quality Index		x	x	x
pH	x		x	
Conductivity	x	x		x
Dissolved Oxygen			x	
Turbidity		x	x	x
NO_3-N			x	
NH_3-N	x		x	
Total N		x	x	
PO_4-P			x	
Total P	x		x	
Total Organic Carbon				x
Dissolved Organic Carbon				x
Chlorophyll a			x	x
TN:TP	x			

VII. Conclusions

Least disturbed conditions were used to describe reference conditions for wetlands in the Lower Missouri River floodplain. These wetlands were initially identified using the USFWS National Wetlands Inventory (NWI) and surrounding land use coverage maps (NLCD 2002). Later in the study, least disturbed reference wetlands were reevaluated according to Disturbance Assessment scores and professional judgment undertaken during field visits. Using these other parameters, principally the Disturbance Assessment, allowed for a more robust selection of wetlands representing least disturbed reference conditions. Moreover, original NWI mapping for wetland classes based on Cowardin *et al.* (1979) were often incorrect, and wetlands had to be reclassified according to observations made in the field and resultant distinguishing characteristics among wetlands in the sample set (section III).

Regional and local factors are forms of external disturbance in wetlands. Omernik Level III ecoregions can account for environmental heterogeneity in the landscape with respect to certain water quality variables, like conductivity, TN:TP ratios, pH, ammonia and total phosphorous. Nonetheless, the impact of some regionally determined variables will still differ by wetland type/class. Structural modifications within wetlands and at their (artificial) boundaries constitute internal disturbances. Wetland classification, though it does not directly relate to disturbance, is able to describe wetlands in different states of ecological recovery or managed states of secession (*e.g.* PUB wetlands). A combination of these factors impacts the ecological integrity of wetlands ecosystems according to water and floristic quality variables (Table 5). The temporal dimension of variations in water quality was not addressed in this study, as it would have required a far more rigorous sampling design. Yet, most water quality variables were found to vary significantly within wetlands, which demonstrates the resilience of wetland ecosystems in their ability to tolerate broad ranges of nutrient and chemical concentrations. The behavior of floristic response variables further characterizes the impacts of different types of disturbance, but also indicates that the impact of some forms of external disturbance can differ by wetland class. Floristic quality attributes (*i.e.* mean conservatism, percent adventives and richness) have also been shown to vary by wetland class. Even so, the Floristic Quality Index score is able to normalize some of this variance and appears to be an appropriate indicator of disturbance in wetlands. Based on this study, wetlands receiving an FQI score of less than 16 are highly disturbed, those between 16 and 19 are moderately disturbed and those above 19 are least disturbed.

External disturbances, especially those related to agrochemical runoff and sedimentation, tended to have more detrimental impacts when combined with internal/structural disturbances (*i.e.* steep shores or other hydrologic alteration). Therefore, the structure of wetlands, their dimensions, depth, flooding-drainage frequency, connectivity, and amount of relief area in littoral zones are major determinants of wetland water and floristic quality.

VIII. Future Implications

Observed ecological information on floodplain wetlands provides a starting point for assessing the potential for ecosystem services delivery under hypothetical management scenarios; whether such scenarios are directed at reconnecting rivers to artificially inactive portions of their floodplains to enhance flood protection, improve water quality, increase regional biodiversity or all of the above. Economic valuation of these services relates to specific functions of connected versus disconnected wetland ecosystems at a combination of spatial scales. Because entire reaches of historically active floodplains have been disconnected from their rivers, the benefits of reconnecting them must be evaluated on a regional basis first (large-scale), wherein the localized economic values could be obtained by integrating proportions of regionally derived values according to the extent that reconnecting specific segments of the floodplain contribute to regional water quality, security and biodiversity. The returns from each function can ultimately be quantified and combined into an economic valuation scheme that reflects regional and local attributes of ecosystem services provision for restored floodplain wetlands. Based on the results of this study, floodplain wetland restoration efforts would be better directed towards restoring historic hydrologic regimes for individual wetlands and wetland complexes.

IX. Data Sources

Assessment of Floodplain Wetlands of the Lower Missouri River, Phase I: Determination of Reference Condition (2005-2007). USEPA award CD-98741801

Assessment of Floodplain Wetlands of the Lower Missouri River, Phase II: Verification of Rapid Assessment Tools Using an EMAP Study Approach (2007-2009). USEPA award R7W0812.

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Appendix A: Phase II Sites (2008-2009)

Latitude	Longitude	AgencyID	County	Location
39.0215	-92.7550	R7W08712-001	Howard	MKT Lake
39.3566	-93.0327	R7W08712-002	Chariton	Cut-off Lake
39.3747	-93.0301	R7W08712-006	Chariton	Cut-off Lake
38.7004	-91.7569	R7W08712-007	Callaway	Mollie Dozier Chute
39.3645	-93.0281	R7W08712-013	Chariton	Cut-off Lake
39.7589	-94.9061	R7W08712-020	Buchanan	Browning Lake
40.1096	-95.2248	R7W08712-021	Holt	Squaw Creek NWR
39.2082	-93.9792	R7W08712-022	Ray	Sunshine Lake
39.5809	-93.2583	R7W08712-023	Chariton	Grassy Lake
39.6237	-93.1574	R7W08712-027	Chariton	Silver Lake
40.0766	-95.2321	R7W08712-032	Holt	Squaw Creek NWR
39.2561	-94.2327	R7W08712-033	Clay	Cooley Lake CA
39.6224	-93.2352	R7W08712-034	Chariton	Swan Lake NWR
39.2484	-94.2329	R7W08712-041	Clay	Cooley Lake CA
40.8203	-95.8475	R7W08712-082	Cass	
40.3287	-95.6884	R7W08712-084	Nemaha	Bullfrog Bend
40.8532	-95.7865	R7W08712-086	Freemont	Forney Lake
42.3122	-96.3243	R7W08712-087	Woodbury	Browns Lake
41.9569	-96.1330	R7W08712-090	Monona	Louisville Bend
39.0842	-92.9371	R7W08712-137	Saline	Big Muddy NWR
39.3255	-93.0483	R7W08712-152	Chariton	Forest Green
38.9874	-92.6875	R7W08712-170	Howard	Franklin Island
39.4051	-93.1027	R7W08712-176	Chariton	Trophy Room
38.7334	-90.4699	R7W08712-179	St. Louis	Crystal Springs GC
40.1335	-95.2851	R7W08712-191	Holt	Old Channel
40.1047	-95.2796	R7W08712-195	Holt	Squaw Creek NWR
39.5766	-93.2419	R7W08712-200	Chariton	Bosworth Hunt Club
40.0939	-95.2749	R7W08712-207	Holt	Squaw Creek NWR
39.5890	-93.2254	R7W08712-208	Chariton	Swan Lake NWR
39.6398	-93.1442	R7W08712-211	Chariton	Swan Lake NWR
42.4351	-96.4385	R7W08712-244	Dakota	S. Sioux City
42.0573	-96.2141	R7W08712-248	Monona	
40.6955	-95.8162	R7W08712-254	Freemont	NRCS
41.9743	-96.1359	R7W08712-256	Monona	Louisville Bend

41.5749	-96.0573	R7W08712-257	Harrison	Corn field
40.6838	-95.8109	R7W08712-258	Freemont	NRCS
39.1887	-93.7877	R7W08712-046	Lafayette	Kerr Orchard
39.4546	-94.9718	R7W08712-049	Platte	Lewis and Clark
39.1811	-93.9696	R7W08712-221	Lafayette	Sunshine Lake
39.3380	-94.8710	R7W08712-225	Platte	Mud Lake
39.7921	-94.8883	R7W08712-226	Buchanan	French Bottoms
41.0754	-95.8219	R7W08712-096	Mills	Folsom Lake
41.0824	-95.8213	R7W08712-262	Mills	Folsom Wetland

Appendix B: Phase I Sites (2005)

Latitude	Longitude	CPCB ID	County	Site Name
39.5001	-95.0290	7100	Platte	Little Bean Marsh
40.0962	-95.2360	7101	Holt	Squaw Creek
40.0698	-95.2641	7102	Holt	Squaw Creek
39.6118	-93.2030	7103	Chariton	Swan Lake
39.6070	-93.1513	7104	Chariton	Swan Lake
39.6219	-93.2347	7105	Chariton	Swan Lake
41.5227	-96.0956	7106	Harrison	Desoto Sand Chute
41.4942	-96.0058	7107	Harrison	Desoto Lake
41.2960	-95.8631	7108	Pottawattamie	Big Lake
42.3055	-96.3311	7109	Woodbury	Browns Lake
42.2766	-96.3319	7110	Woodbury	Snyder Bend Lake
41.4814	-96.0010	7111	Pottawattamie	Wilson Island
42.0480	-96.1757	7112	Monona	Blue Lake
42.0084	-96.1902	7113	Monona	Middle Decatur Bend
41.7419	-96.0311	7114	Harrison	Round Lake
42.0083	-96.2338	7115	Monona	Tieville-Decatur Bend
40.9895	-95.8053	7116	Mills	Keg Lake
39.3509	-94.2316	7117	Clay	Cooley Lake

Appendix C: CPCB Reclassification Examples

Palustrine Emergent (PEM)

Elk Creek, R7W08712-211

Palustrine Aquatic Bed (PAB)

Cooley Lake North, R7W08712-033

Palustrine Unconsolidated Bottom (PUB)

Bosworth Hunt Club, R7W08712-200

Palustrine Unconsolidated Emergent Aquatic Bed (MIX)

Crystal Springs GC, R7W08712-179

Appendix D: Characterization of least disturbed water quality conditions

Reference Water Quality Parameters for Palustrine Aquatic Bed Wetlands (PAB)

	Lower Reach			Upper Reach		
	Mean	**Standard Dev**	**Range**	**Mean**	**Standard Dev**	**Range**
Depth (m)	**0.71**	0.2	*0.49-0.85*	**1.12**	0.54	*0.71-1.73*
pH	**7.37**	0.64	*6.96-8.11*	**8.03**	1.1	*7.36-9.31*
Conductivity (umS/cm)	**0.213**	0.06	*0.15-0.25*	**0.35**	0.05	*0.20-0.40*
Turbidity (NTUs)	**26**	28	*8.0-59.0*	**13**	11	*3.0-25.0*
Dissolved Oxygen (mg/L)	**4.2**	2.3	*1.53-5.9*	**5.45**	3.62	*3.32-9.63*
Temperature (^{o}C)	**25.4**	1.7	*23.5-26.8*	**24.9**	4.11	*20.4-28.5*
Nitrate (mg/L)	**0.03**	0.01	*0.02-0.05*	**0.08**	0.02	*0.06-0.13*
Ammonia (ug/L)	**40**	11	*31-52*	**68**	43	*42-117*
Total Nitrogen (mg/L)	**0.92**	0.25	*0.67-1.17*	**0.79**	0.45	*0.39-1.28*
Phosphate (ug/L)	**55**	54	*13-115*	**210**	331	*7-593*
Total Phosphorous (ug/L)	**211**	163	*85-396*	**354**	432	*16-842*
TN:TP by mass	**5.9**	3.2	*2.3-7.9*	**10.3**	12.1	*1.0-24*
Chlorophyll a (ug/L)	**25.2**	22.2	*0.7-44.1*	**7.5**	8.4	*2.2-17.2*
Total Organic Carbon (mg/L)	**11.5**	4.1	*6.8-10*	**7.9**	2	*5.6-9.2*

Reference Water Quality Parameters for Palustrine Emergent Wetlands (PEM)

	Lower Reach			Upper Reach		
	Mean	**Standard Dev**	**Range**	**Mean**	**Standard Dev**	**Range**
Depth (m)	**0.48**	0.19	*0.37-0.70*	**0.91**	0.54	*0.49-1.52*
pH	**7.53**	0.45	*7.25-8.04*	**8.32**	0.03	*8.29-8.35*
Conductivity (umS/cm)	**0.19**	0.08	*0.13-0.29*	**0.7**	0.11	*0.57-0.76*
Turbidity (NTUs)	**103**	102	*17-217*	**51**	26	*23-73*
Dissolved Oxygen (mg/L)	**6.07**	1.36	*4.52-6.58*	**6.08**	1.26	*4.63-6.90*
Temperature (^{o}C)	**29.3**	2.2	*26.9-31.3*	**25.5**	2.7	*23.6-28.6*
Nitrate (mg/L)	**0.04**	0.02	*0.02-0.06*	**0.09**	0.05	*0.03-0.13*
Ammonia (ug/L)	**84**	97	*24-196*	**63**	12.1	*49-71*
Total Nitrogen (mg/L)	**1.15**	0.71	*0.66-1.97*	**1.38**	0.37	*0.96-1.66*
Phosphate (ug/L)	**79**	62	*12-135*	**27**	10	*16-36*
Total Phosphorous (ug/L)	**271**	106	*185-391*	**109**	24	*83-130*
TN:TP by mass	**4.8**	3.3	*1.7-8.3*	**12.6**	1.7	*11.6-14.6*
Chlorophyll a (ug/L)	**25.9**	30.6	*7.8-61.3*	**33.3**	15.6	*16.4-47.1*
Total Organic Carbon (mg/L)	**11.1**	7.7	*6.5-19.9*	**9**	1.6	*7.3-10.4*

Reference Water Quality Parameters for Palustrine Unconsolidated Emergent Aquatic Bed (MIX)

	Lower Reach			Upper Reach		
	Mean	**Standard Dev**	**Range**	**Mean**	**Standard Dev**	**Range**
Depth (m)	**0.34**	0.12	*0.24-0.48*	**0.91**	0.58	*0.27-1.41*
pH	**6.6**	0.87	*5.59-7.07*	**8.02**	0.76	*7.33-8.84*
Conductivity (umS/cm)	**0.197**	0.11	*0.07-0.27*	**0.547**	0.184	*0.34-0.70*
Turbidity (NTUs)	**88**	100	*9-200*	**38**	35	*13-63*
Dissolved Oxygen (mg/L)	**1.43**	0.65	*1-2.19*	**6.96**	3.69	*4.73-11.22*
Temperature (^{o}C)	**25.8**	0.6	*25.1-26.3*	**28.5**	1.9	*26.3-30.1*
Nitrate (mg/L)	**0.02**	0.01	*0.01-0.05*	**0.33**	0.37	*.01-0.59*
Ammonia (ug/L)	**62**	24	*45-164*	**92**	89	*38-195*
Total Nitrogen (mg/L)	**1.84**	0.76	*1.3-3.79*	**1.98**	1.47	*0.086-3.66*
Phosphate (ug/L)	**309**	277	*72-614*	**115**	121	*75-251*
Total Phosphorous (ug/L)	**923**	467	*384-1200*	**276**	156	*123-435*
TN:TP by mass	**2.9**	0.8	*2-3.4*	**7.8**	4.3	*3.2-11.7*
Chlorophyll a (ug/L)	**86.2**	79.2	*15.7-171.8*	**127.8**	142	*38.1-291.4*
Total Organic Carbon (mg/L)	**16.5**	3.7	*14.2-20.9*	**11.3**	2.2	*9.3-13.7*

Appendix E: Parameters, instruments, methods and forms used in the study

Parameters	Container	Instrument/Method	Method Citation	Detection Limit	Holding Time	Preser-vation
Laboratory measurements and analysis						
Total Phosphorus	1L Amber Glass	Digestion @ 250°F and 15 psi, Lachat QuikChem 8500	Ebina *et al.* 1983	5 µg/L	5 days	4 deg. C
PO_4-P	1L Amber Glass	Lachat QuikChem 8500	21st ed. Standard Methods	1 µg/L	48 hrs	4 deg. C
Total Nitrogen	1L Amber Glass	Digestion @ 250°F and 15 psi, Lachat QuikChem 8500	Ebina *et al.* 1983	0.01 mg/L	5 days	4 deg. C
Ammonia-N (NH_3-N)	1L Amber Glass	Lachat QuikChem 8500	21st ed. Standard Methods 4500 NH_3-G	1 µg/L	24 hrs	4 deg. C
Nitrate-N	1L Amber Glass	Lachat QuikChem 8500	21st ed. Standard Methods 4500 NO_3-F	0.01 mg/L	48 hrs	4 deg. C
Nitrite-N	1L Amber Glass	Lachat QuikChem 8500	21st ed. Standard Methods 4500 NO_2-B	0.01 mg/L	48 hrs	4 deg. C
Chlorophyll *a*	1L Amber Glass	Optical Tech. Devices, Ratio-2 System Filter Fluorometer	21st ed. Standard Methods 10200-H	1.0 µg/L	30 days	4 deg. C
Herbicides	1L Amber Glass	Gas Chromatography/Mass Spectrometry	Thurman *et al*. 1990	0.05-0.1 µg/L	7 days	4 deg. C
TOC/DOC	1L Amber Glass	Shimadzu TOC Analyzer (TOC-5000A)	21st ed. Standard Methods	0.1 mg/L	7 days	4°C, add H_3PO_4 pH
In situ measurements						
pH	none	Horiba U-10 Water Quality Checker	21st ed. Standard Methods	0.1 SU		
Conductivity	none	Horiba U-10 Water Quality ıecker	21st ed. Standard Methods	1 µS/cm		
DO	none	Horiba U-10 Water Quality Checker	21st ed. Standard Methods	0.1 mg/L		
Turbidity	none	Horiba U-10 Water Quality Checker	21st ed. Standard Methods	1.0 NTU		
Air Temp.	none	Horiba U-10 Water Quality Checker	21st ed. Standard Methods	0.1 deg. C		
Water Temp.	none	Horiba U-10 Water Quality Checker	21st ed. Standard Methods	0.1 deg. C		
Secchi Transparency	none	Secchi disk	Wetzel and Likens 1979	-		

R7W08712-___________

WETLAND WATER QUALITY FORM

Central Plains Center for BioAssessment
Kansas Biological Survey

Date: **Time:** **Evaluator(s):**

NAME OF WETLAND:

Sample Transect Center: Lat/Long *NAD83*	___________________°**N** ________________°**W**					
Wetland Class *circle dominant*	____**% Uncons. bottom** ______**% Emergent** _____**% Aquatic Bed**					
Transect depths[1] (m) *circle max depth*	**1**					
	2					
	3					

Transect measures[2]	**1**	**2**	**3**	**Alt**
Secchi depth (m)				
pH				
Conductivity (mS/cm)				
Turbidity (NTU)				
Dissolved oxygen (mg/L)				
H_2O temp. (^oC)				
Air temp. (^oC)				
Sample type[3] (V or OW)				

Site Checklist:

- Composite Sample ☐
- Chlorophyll *a* ☐
- Macroinvertebrates ☐
- Disturbance[4] ☐
- Duplicate (X) ☐
- Spike (S) ☐

[1] Average depth should be calculated from a minimum of three equally spaced transects perpendicular to the long axis of the wetland and consisting of no less than five measurements including edge at one meter from shoreline.
[2] In-situ measurements from transect-long axis intersect. "Alt" refers to alternative sampling sites that represent minority macrohabitat type (*i.e.* vegetated in open water or vice versa).
[3] Indicate macrohabitat: V-vegetated, OW-open water.
[4]The Wetland Disturbance Assessment (over) focuses on *Wetland Attributes* to score how well equipped the wetland is able to deal with disturbance (or how it is currently dealing with it), *Reference Indicators* as those characteristics that would demonstrate barriers to human disturbance or otherwise indicate pristine conditions for wildlife or hydrologic interaction in the landscape, and *Disturbance* as evident physical perturbations or known observable impairments that may occur as a result of them, such as excessive sedimentation or the proliferation of invasive species.

QA signature(s)____

WETLAND DISTURBANCE ASSESSMENT	R7W08712 - _______
I. Wetland Attributes. *Score to a maximum of 15 points.*	
1. Wetland Size. Wetland boundaries for delineation are defined by evidence of changes in hydrology and may be fairly wide, especially in areas where there is gradual relief.	
1 pts <25 acres 2 pts 25-50 acres 3 pts >50 acres	
2. Natural Buffer Width. Natural wetland buffer includes woodland, prairie, surrounding wetlands and water bodies. The buffer width should be estimated by taking the average of buffer widths in each cardinal direction from the center of the wetland.	
1 pts <10m 2 pts 10-50m 3 pts >50m	
3. Land Use. Surrounding land use is defined as dominant visible land-use adjacent to and upland from the wetland area, including the natural buffer.	
1 pts Intensive urban, industrial or agricultural activities	
2 pts Recovering land, formerly cropped or a mix of intensive and natural uses	
3 pts Landscape is relatively undisturbed by human activities	
4. Hydrology. Determine the dominant water source based on direct observation of the wetland and its position in the landscape relative to other water bodies or hydrologic features.	
1 pts Precipitation fed wetland, no recognizable inflowing water	
2 pts Fed by seasonal surface water, stormwater drainage and/or groundwater	
3 pts Source is clearly an adjacent lake or an unobstructed inflowing stream	
5. Vegetation Coverage. Refers to aerial coverage of wetland flora or the proportion of vegetated area to open water. Open water area does not include adjacent lakes.	
1 pts <20% 2 pts 20-40% or >70% 3 pts 40-70%	
Wetland Attributes Total	
II. Reference Indicators. *Score one point for each (to be added).*	
Wetland located in a National Wildlife Refuge, Conservation Area or otherwise protected by local, state or federal laws	
Amphibian breeding habitat quality is pristine	
Waterfowl habitat quality is pristine	
Endangered/Threatened Species present	
Interspersion as macrohabitat diversity characterized by a high shore to surface area ratio	
Connected to water bodies (and wetlands) during high-water, located within a natural complex and/or part of a riparian corridor.	
Reference Indicators Total	
III. Disturbance. *Score one point for each (to be subtracted).*	
Sedimentation suggested by sediment deposits/plumes, eroding banks/slopes, and/or turbid water column	
Upland soil disturbance such as tilled earth or construction activities	
Cattle present within or on lands adjacent to the wetland	
Excessive algae present in large, thick mats	
>25% invasive plant species	
Steep shore relief (score 2 pts if more than 50% of wetland edge)	
Altered hydrology shows deviation from historical regime and does not attempt to preserve/restore it	
Wetland is managed as a fishery or hunting club (*i.e.* water level is manipulated to limit growth of emergents)	
Disturbance Total	
Total Score (Wetland Attributes + Reference Indicators – Disturbance)=	